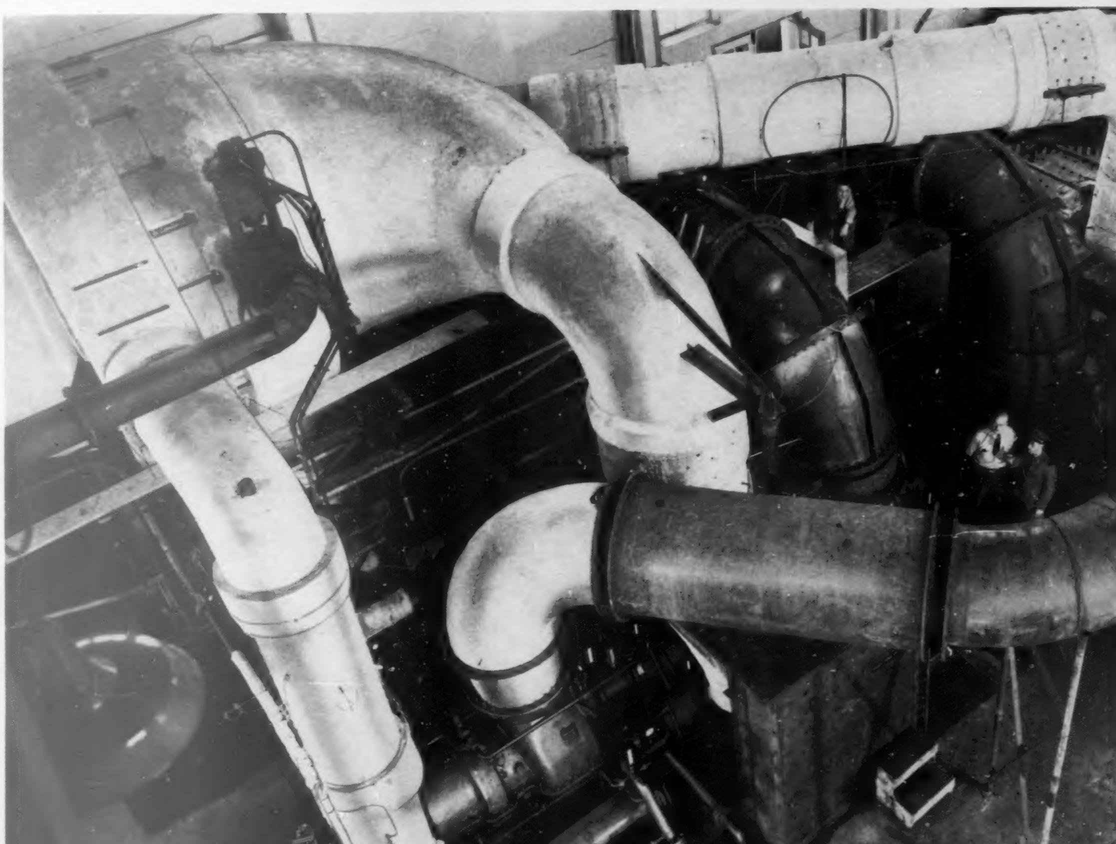
ALLIS-CHALMERS

Electrical Review



First Quarter, 1946

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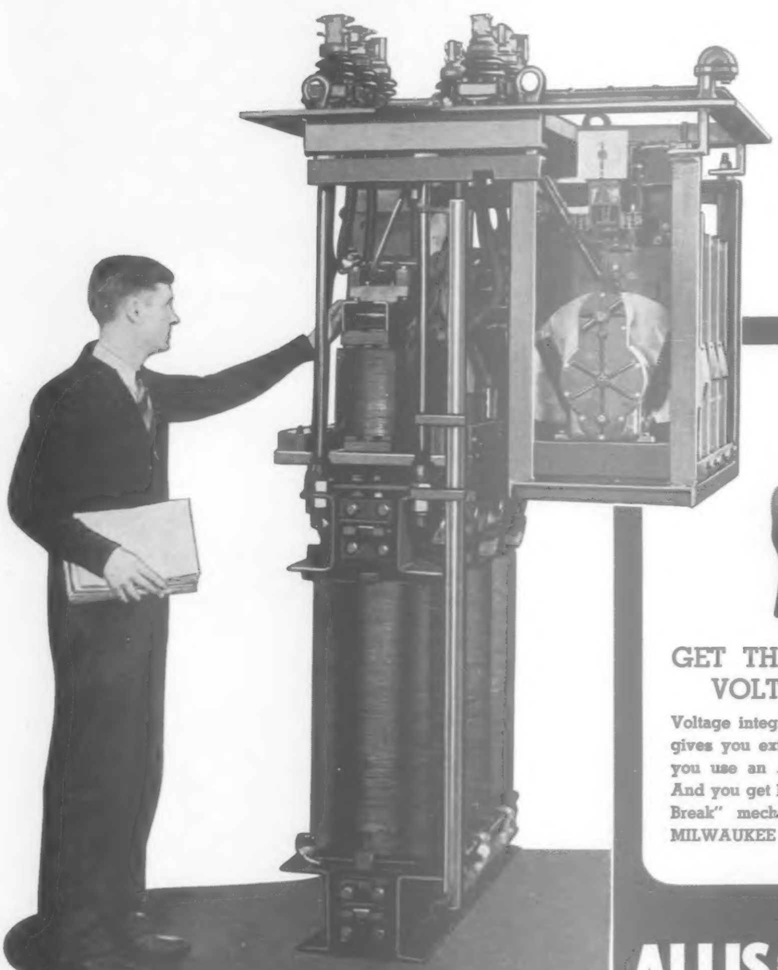

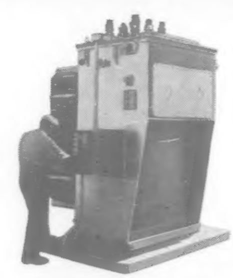

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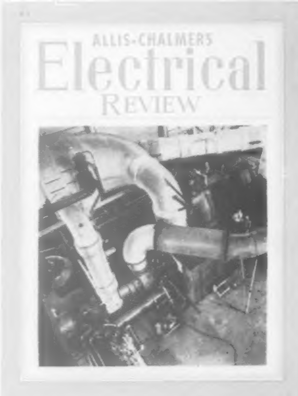
⅝% STEP REGULATORS



THE 3500 HP GAS TURBINE (cover) has been operating successfully on an experimental basis at the U. S. Naval Experiment Station, Annapolis, at over 1350 deg. F, highest temperature yet reached in a gas turbine. Built by Allis-Chalmers, working with the Navy, the unit is pioneering a promising new field that lies ahead for gas turbine power generation. Further information of gas turbine developments is scheduled for an early issue of the ELECTRICAL REVIEW.

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ALLIS-CHALMERS Electrical REVIEW

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Contents

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Solving the Shock Problem

CHARLES ROCKWOOD
Development Engineer, Control Section
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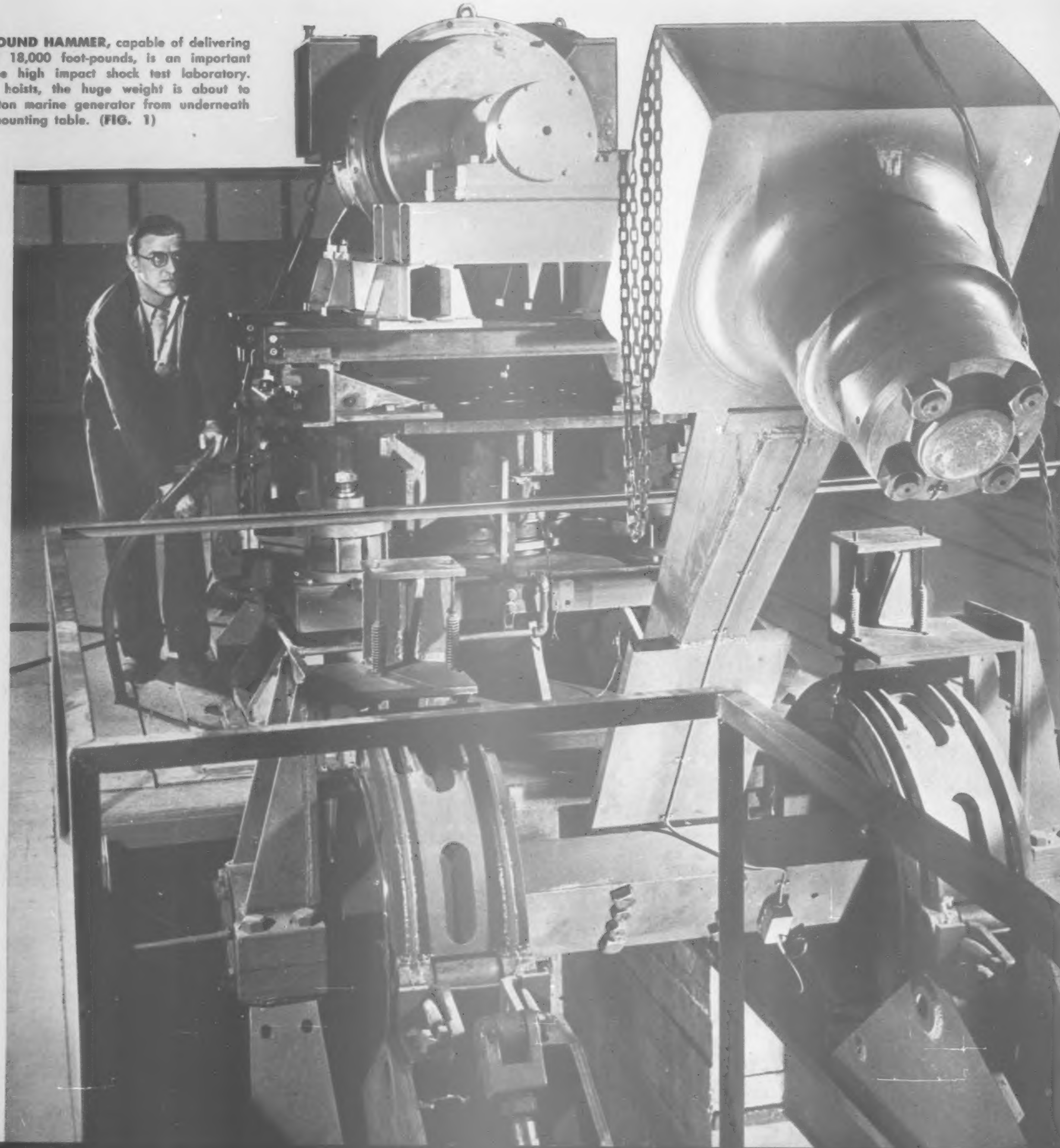
A 3000-POUND HAMMER, capable of delivering a blow of 18,000 foot-pounds, is an important part of the high impact shock test laboratory. Raised by hoists, the huge weight is about to strike a 2-ton marine generator from underneath the shock-mounting table. **(FIG. 1)**



ELECTRICAL equipment was used in World War II to an extent unheard of just a few years before, and it is now apparent that it would be a major undertaking even to list all of the numerous pieces of electrical equipment used on any modern naval vessel. These would range all the way from almost unbelievably intricate electrical computing devices for integrating masses of gunfire data in the twinkling of an eyelash to the gigantic electric motors which drive some of our great ships through the seas at speeds which only a few years ago seemed fantastic.

All of these devices have at least one thing in common—they are all operated by electrical control equipment of one sort or another. How completely a great fighting ship can be paralyzed by failure of any of this equipment or its associated control was one of the dearly bought lessons of the earlier days of World War II.

It was quickly learned that many electrical control devices which were completely satisfactory for ordinary industrial service were far more vulnerable to enemy attack than were the great steel hulls and structures for which they were literally the brains and the nerves. It was found, for instance, that underwater explosions such as those resulting from magnetic mines, depth charges, and aerial bombs dropped near a ship, while causing only minor damage to the hull of the ship, could raise havoc with the vessel's entire electrical system by disrupting the numerous electrical circuits so necessary to continued operation in battle.

TOLD HERE FOR THE FIRST TIME . . . How shock from aerial bombs and torpedo "near misses" called for redesign of practically all naval control equipment.

Probably no single instance gave more dramatic or tragic proof of this than the sinking of the two great British ships, H.M.S. Repulse and H.M.S. Prince of Wales, by a Japanese air attack as they steamed north from Singapore. The first bombs dropped exploded in the water near the ships, and the resulting shock from the underwater explosions so disrupted the vast systems of electrically driven equipment that the ships were left with neither the ability to maneuver nor to fight back against the repeated attacks which sent them to the bottom of the South China Sea.

Shock causes casualties

Some picture of the magnitude of the shocks which may take place can perhaps be gained from the fact that it is estimated that some points aboard ship attain an instantaneous acceleration equal to 1,000 times the acceleration of gravity, or about 32,000 ft. per second per second. Under such conditions a 150 pound man would in effect weigh 150,000 pounds for the few microseconds duration of the acceleration. The total upward movement of the ship might be around three-fourths of an inch. The most frequently reported cases of damage to personnel were broken ankles.

Thus it was that manufacturers of electrical controls for use by the Navy faced the assignment of developing complete lines of controller equipment capable of withstanding the effects of sudden, mechanical shocks of great magnitude. And to do so not only without being permanently damaged, but in many cases without even allowing so much as a momentary interruption of the circuits being controlled.

In this connection it must be mentioned that before the development of shockproof equipment could progress very much, it was necessary to develop testing equipment and standardized procedures for its use. Considerable research had to be done by the Navy Department to estimate the nature of the shocks which could be expected. Extensive data was collected on shocks which occurred on shipboard under simulated as well as actual battle conditions.

Develop shock-test machine

The testing machines which were developed as a result of this research simulate the shocks of battle by using the impact of a massive hammer which swings about a horizontal pivot under the influence of gravity, striking a heavy steel anvil plate upon which the equipment to be tested is mounted. Figure 1 and Figure 2 show two different sizes of such machines. The weight of the equipment to be tested determines which machine is to be used. A detailed discussion of high impact shock testing is left to another article since a complete treatment of this subject would necessarily be too lengthy for inclusion here.

There were two major phases of the problem of designing shockproof equipment.

The first of these was to produce equipment which would not sustain any actual structural damage. It is not very difficult to add more strength against shock to a metal structure by making parts lighter and stronger, but much of the structure of a controller was made up of insulating materials, most of which were quite brittle. Parts made from such materials were completely shattered on the shock testing machines which were set up in key electrical manufacturing plants throughout the country.

Much credit is due to the engineers and scientists of the plastics, glass, and ceramic industries who, working with the Navy, developed a number of excellent electrical insulation materials having sufficient impact strength to enable electrical manufacturers to solve the problem of structural failures.

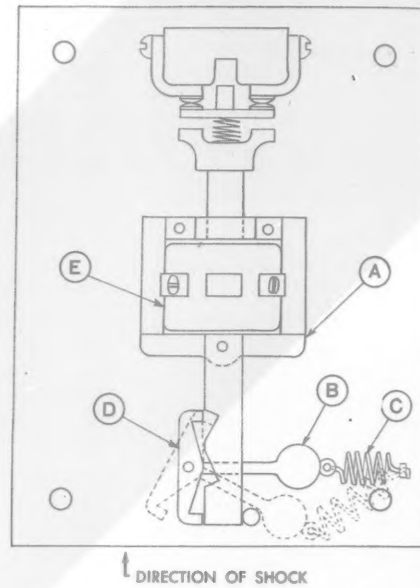
The second phase of the problem was to produce devices constructed so that an extremely severe mechanical shock would not produce false operation. Thus, if an electric switch is mounted on a bulkhead aboard ship, and a near miss by a bomb gives the bulkhead a severe bump, contacts which are closed before the explosion must still be closed afterward, and contacts which are open are expected to stay open.

On many devices such as relays and pilot switches it was necessary to prevent even a momentary interruption of the circuits. This was true where a pushbutton, relay, or other pilot device maintains the control circuit of a magnetic contactor, which in turn would be permanently dropped out.

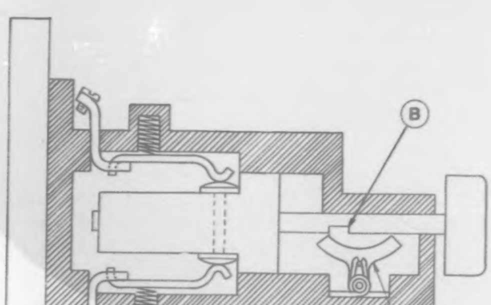
Four shock-proofing methods

Methods for mitigating the effects of shock upon control

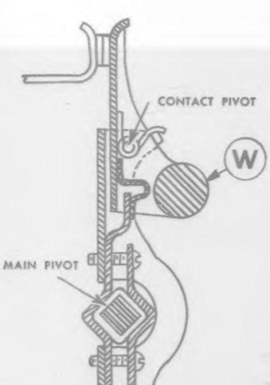
LIGHTER PIECES of equipment are normally mounted on this medium weight shock testing machine designed to give a blow of 2000 foot-pounds. Laboratory contains a third, smaller hammer. **(FIG. 2)**



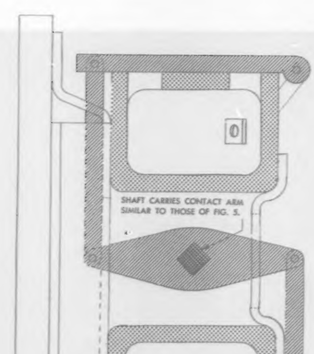
INERTIA INTERLOCK on vertical contactor places weight B so that shock causes it to move down. This closes latch D preventing armature A of magnet E from moving down, as normally happens. Similar action prevents downward shock from moving clapper up when contactor is de-energized. **(FIG. 3)**



MANUAL PUSH-PULL switch with inertia interlock has moving member thrown outward by force of shock. Shock also rotates latch A in such a way that it catches notch B in the switch element to prevent such action. **(FIG. 4)**



CONTACT STRUCTURE for balanced contactor must have complete static balance about both pivot points, achieved by the counterweights W. **(FIG. 5)**



UNBALANCED magnet clappers are linked together in such a manner that the entire linkage is balanced. **(FIG. 6)**

operation may be roughly divided into four different classifications as follows:

1. Shock mountings
2. Gravity or inertia interlocks
3. Balanced construction
4. Positive locking

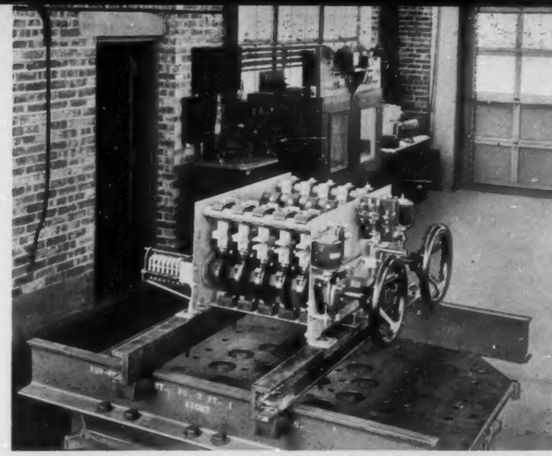
The first classification, shock mounting, through the use of vibration or shock absorbers as part of the mounting device, underwent a very great amount of development during the war, not only for the protection of electrical equipment but for mounting all types of instruments and auxiliary machinery on shipboard. In the field of control it found greatest application in the mounting of entire control boxes on the ship. Separate shock mountings are also being used for mounting sensitive instruments and devices such as regulators, etc., to panels. The use of this method can at best only lessen the shock so that, even where it is used, the individual control devices must usually be of special design. A certain amount of resilience can be built into the control cabinet itself since it has been observed that equipment which is shock tested in its enclosure is less subject to damage than the same equipment mounted directly on the shock-testing equipment.

The second method of making equipment to withstand shock is the one which found widest use earlier in the war. This is the method of using inertia interlocks. By this means it was possible to modify many standard control devices so that they would not be operated by severe blows. Figure 3 shows a sketch of a standard vertical contactor with a typical inertia interlocking device. The weight is so placed that any shock which would tend to drop out the contactor when it is closed, or to close it from the open position, would cause the weight to move from its free position and block any movement of the contactor element. Figure 4 shows a similar interlock for protecting a manual push-pull switch. The method proved fairly successful but it was found that the adjustment of the interlocks was in many cases quite critical. Furthermore, many of the devices would withstand severe shocks while shocks of somewhat lesser magnitude operated the controls without moving the interlocks sufficiently to prevent false operation.

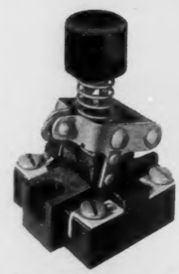
Because of the difficulties which have been mentioned, this method of shock protection has fallen into disfavor.

Parts must balance statically

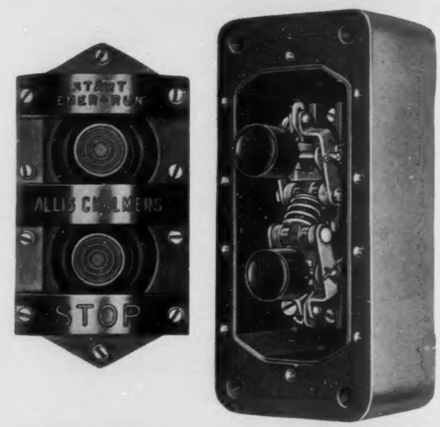
In the third method of shockproofing, it is necessary to design the apparatus so that all parts which move when the device is operated are statically balanced in all of the planes in which movement takes place. This means that every moving part must be statically balanced about a pivot point. Otherwise it must be interlinked with other parts in such a way that a shock which tends to move that part of the linkage in the direction in which it is free to move will at the same instant tend to put an equal and opposite reaction on that part due to the acceleration forces on the other parts to which it is linked. Figures 5 and 6 show contact and magnet structures of a contactor which employs these principles. It can be noted how the clappers on the magnet structure are linked together in such a way that, while each clapper is not balanced of itself, the entire linkage is balanced. Figure 8 shows a photograph of a pushbutton element in which the swinging weight on the end of an arm counterbalances the unbalanced weight of the button and its shank. Figure 9



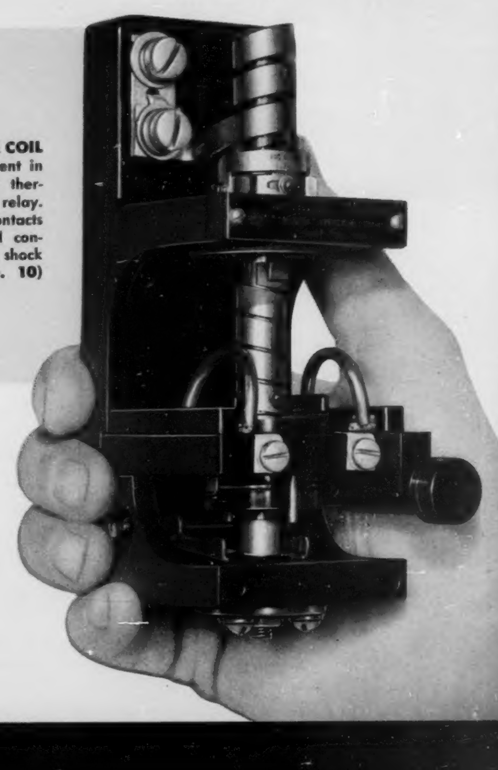
TO TEST the positive mechanical wedging or locking action used in design of shockproof equipment, this pair of generator set-up switches with cam-operated contacts is awaiting the hammer blow. (FIG. 7)



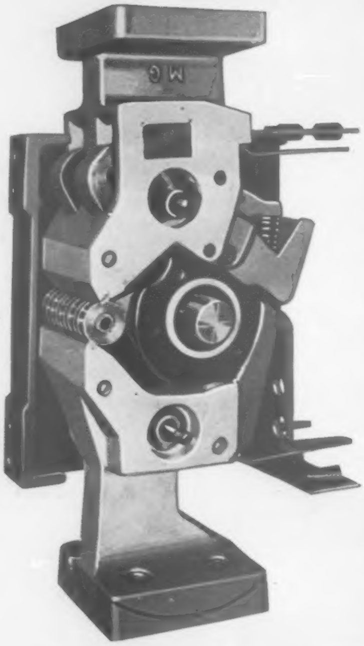
SMALLEST of control components needed redesign in many cases. Counter-balance weight (roller) is behind spring in this pushbutton element. (FIG. 8)



SHOCK THRUST is balanced in this maintained type pushbutton station by a counter-thrust from the opposite half of the mechanism. (FIG. 9)



UPPER HEATER COIL carries the current in this shockproof thermal overload relay. Light spring contacts and balanced construction insure shock resistance. (FIG. 10)



FROM A CAPTURED German submarine, this 2000 amp contactor has auxiliary contacts at the right for making, breaking circuits. Assembly is about 20 inches high. (**FIG. 11**)

shows a photograph of the inside of a maintained pushbutton station using two of these elements linked together and equipped with a throwover spring. Here the heavy counterweights are omitted since the two elements are linked together and balance each other.

One of the most difficult problems of the entire program was the development of a thermal overload relay for high shock service. This was made the more difficult by the fact that the relay had to withstand shock without tripping while carrying full load motor current. This means that it had to maintain positive contact under heavy shock at just below the point where it would trip due to overload. Figure 10 is a photograph of a thermal overload relay, with ambient temperature compensation, which was developed for this service.

Positive locking proved versatile

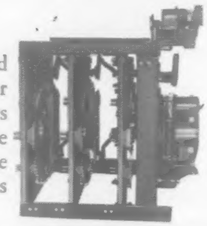
The fourth category of shockproofing — that of using positive mechanical locking or wedging action — takes in a wide variety of possibilities. It would include such devices as cam-operated switches where forces on the contacting member due to shock do not cause any reaction tending to turn the operating cam when it is in either the open or closed position. Figure 7 is a photograph of such a contactor mounted on the shock-testing machine. This type of contactor was extensively used on the Destroyer Escort vessels.

Figure 11 shows an interesting design of a cam-operated contactor removed from a captured German submarine, ample testimony that our enemies, too, had problems in this direction. Note that the rollers which are wedged into the tapering space between the contacts never make or break the circuit. This function is carried on by the auxiliary contact which shunts the main switch. On the other hand, under shock the auxiliary contact may bounce open momentarily without disturbing the circuit, since the rollers are wedged tightly between their contact shoes. Note the extensive use of structural parts made of moulded high impact plastic material in this contactor.

Many of the severe shock problems solved by control designers have little relation to peacetime requirements. On the other hand, many improvements in design and in material brought about through war will be of direct value in postwar controls, particularly for mountings subject to occasional shock. Heavy construction equipment, as well as marine, rail, and air transport, are a few of the points that will benefit from better controls as a result of wartime shockproofing.

New Products

Power Transformers Use New Load Ratio Control



A new tap-changing under-load mechanism now available for large size power transformers permits operator to regulate large circuits as accurately and change tap positions as frequently as on small residential feeders.

Incorporated features are quick-break elkonite contacts, unit construction, drive motor under oil, and balance spring self-snubbing action. Entirely eliminated are the undesirable aspects of interlocking systems between breakers and dial switches, external gears and motors, and position switches heretofore necessary.

Drum For Severe Starting Duty Has 13 Points

Developed for regulating and starting duty on large wound-rotor motors, a new drum has 13 balanced points for acceleration and regulation and is rated 600 amperes, 1,000 volts continuously. It can be operated manually or electrically and provides contact wipe and roll on each operation, plus mechanical contact-breaking action to prevent freezing of contacts.

Air Blast Breaker Serves Two Functions

Using prestored energy of compressed air for breaker operation and circuit interruption, an oil-less air blast circuit breaker is announced for application at voltage ratings of 7.5 kv and 15 kv where interrupting capacities of 250,000 kva and 500,000 kva are required.

Arcing contacts in an interrupting chamber move along the axis of the air blast orifice. A unique refractory throat behind the orifice, physical arrangement of the arcing contacts, and efficient direction of the compressed air stream provide a high degree of limitation and control of arc energy and of arc products obtained.

New Design Completely Encloses Large Motors

Overall re-design of the ventilation heat-transfer system distinguishes a new line of outdoor weatherproof totally enclosed motors in large sizes ranging to over 2,000 horsepower. Designed with normal torque and normal starting current, these new motors are expected to find wide application in central power plant service and the chemical industry as well as general industrial uses.

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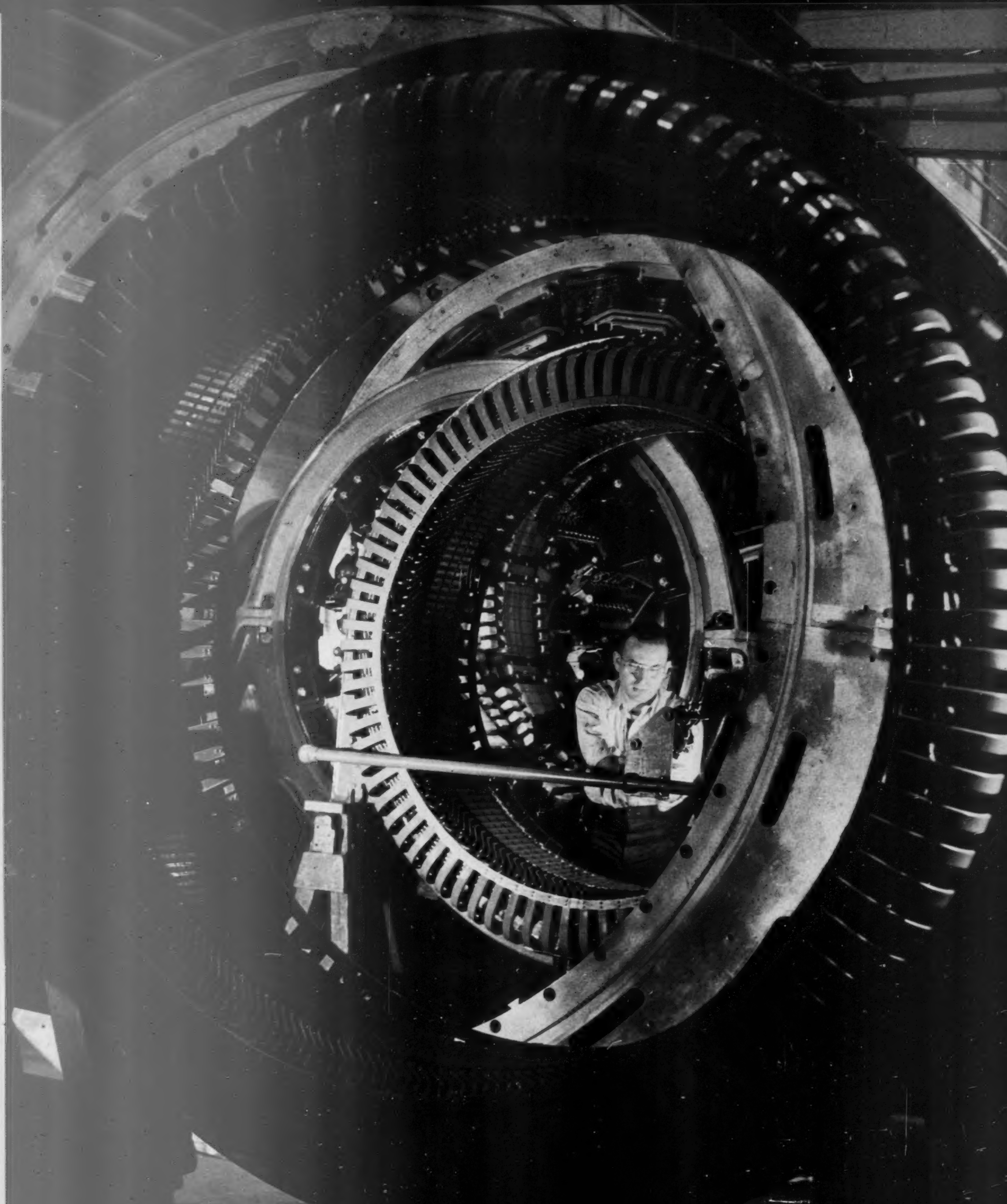
MORE FACTS about these new products are available on request. Write the Allis-Chalmers ELECTRICAL REVIEW, Allis-Chalmers, Milwaukee 1, Wisconsin.



CURVE UPON CURVE creates the effect of a forest of stators, shown awaiting assembly on an Allis-Chalmers erection floor.

Control That Speed

G. BYBERG and E. H. FREDRICK
Motor-Generator Section
Allis-Chalmers Mfg. Co.

Besides the wound rotor induction motor, other more efficient adjustable-speed a-c drives are used for larger installations. The Kraemer system and others are described here in this fourth part of a series on motor speed control.

IN order to utilize desirable characteristics of alternating current motors certain types of drives employ a direct-current circuit as a convenient means of regulating the speed of the final a-c driving unit. Such drives as the variable frequency induction frequency converter, discussed in Part III of this series, and the Kraemer system, herein described, are representative of this type.

Before proceeding to the types of adjustable-speed drives employing the wound rotor induction motor as the medium of speed control, it will be in order to mention briefly another type of variable frequency system. In this system of drive the variable frequency is obtained from a salient pole type synchronous generator driven by means of a direct current motor which, in turn, is supported by a synchronous or induction motor-generator set. Speed adjustment is obtained by a combination of variable voltage on the supporting d-c generator and field-weakening on the d-c motor driving the variable frequency a-c generator. This system ordinarily is more expensive than most other systems of adjustable speed drives because all units must be of full capacity (as shown in Figure 3) but, as in the case of all drives using d-c machines, has a very wide speed range on a constant torque basis. Its main recommendation lies in the possibility of using frequencies higher than the standard established frequencies to supply the ultimate driving motor or motors. This feature is of importance where motor speeds above 3600 rpm are required.

In Figure 1 is shown a 600 kw, 400 cycle d-c to a-c inverter motor-generator set used to power high speed induction motors for testing of aircraft parts. This unit was designed to operate over a 10 cycle to 400 cycle range, which represents a 40:1 ratio on the speed of the final drive motors.

Wound rotor induction motor

The use of wound rotor motors as a medium for providing adjustable speed has long intrigued the electrical industry since the days when this type of motor was developed simultaneously by three inventors in three different countries. Numerous ingenious schemes utilizing this type of machine have been developed in an effort to overcome its inherent disadvantages when used alone on adjustable-speed work. The two main problems to overcome are: (a) the relatively great losses in the secondary circuit, and (b) the instability in speed with varying or fluctuating loads.

Almost all adjustable-speed systems using the wound rotor endeavor, therefore, to reduce to the greatest extent possible these disadvantages. If the slip power loss can be salvaged, either by returning a portion of it to the line or to the main drive motor shaft, the first of the disadvantages can be appreciably minimized.

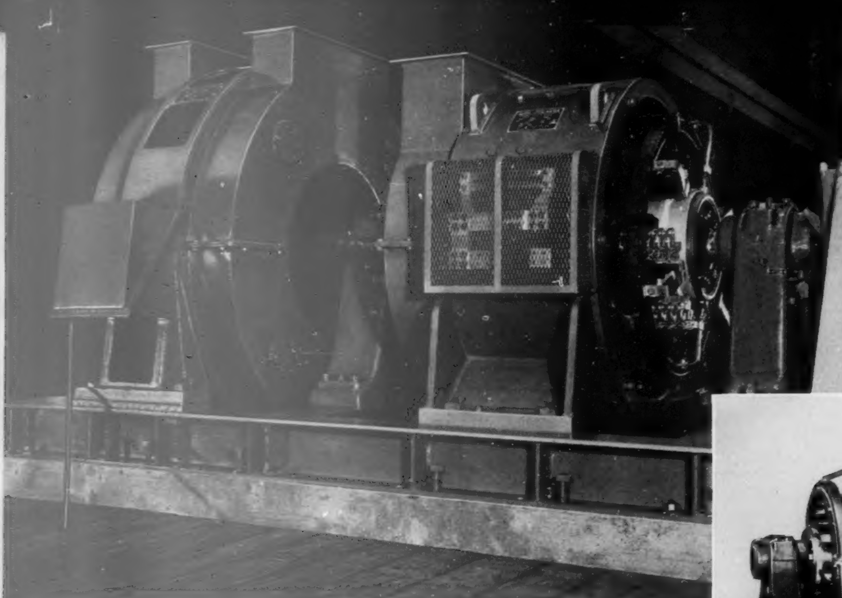
As is well known, the loss in the secondary circuit of a wound rotor motor is a function of the hp output and the slip, or, in other words,

$$\text{Hp loss} = \frac{\text{Hp Output} \times \%\ \text{Slip}}{100 - \%\ \text{Slip}}$$

From this it may readily be determined what the losses will be at any given per cent speed reduction and for drives of different load characteristics. For example, for a load where the horsepower varies as the cube of the speed the maximum loss will occur at 66⅔ per cent speed and will be 50 per cent of the output at that speed or 15 per cent of the rated full speed output. For a load varying as the square of the speed the maximum loss occurs at 50 per cent speed, where it is equal to the output at that speed or 25 per cent of rated full speed output. For a constant torque drive the secondary losses are inversely proportional to speed and the maximum will be at zero speed where it will equal rated full speed horsepower.

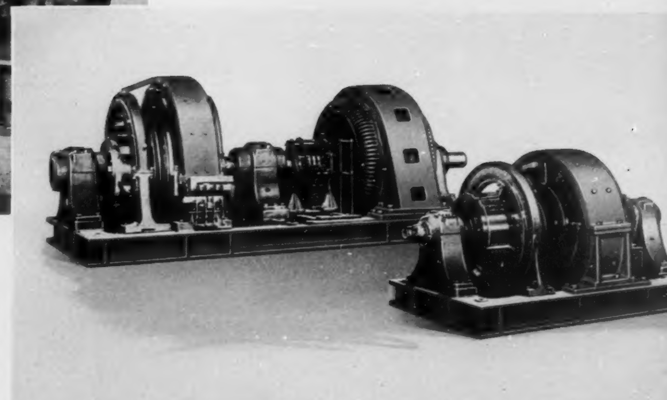
The method of reclaiming the secondary power determines the torque characteristics of the drive; or, in other words, the characteristics of the driven load determines the method. If the power is returned to the electrical power supply the drive will have a constant torque characteristic. If the power is returned to the main drive wound rotor induction motor shaft, a constant horsepower characteristic results. This is shown diagrammatically in Figure 4.

Many ingenious methods have been developed to achieve the purposes mentioned above, most notable of which are the Kraemer system, the Scherbius system, and the LeBlanc system, the latter two to be discussed in a later article. All of these systems employ some form of counter-emf machine connected to the secondary of the wound rotor motor. The result is a condition analogous to that in the armature of a direct current machine, where the current flowing is the result of the difference between the impressed and the counter-emf. In this manner the second objection of speed variation with varying load is minimized and a very stable speed characteristic is obtained.



WIND TUNNEL DRIVE power is provided with 600 kw 10/400 cycle a-c generator driven by an 885 hp, 600 volt d-c motor. (FIG. 1)

MAIN DRIVE UNIT and synchronous converter for a 514/257 rpm constant horsepower Kraemer unit are shown below. This type of drive is occasionally used on large installations requiring relatively narrow speed range. (FIG. 2)



Kraemer system of speed control

The Kraemer system is one of the most familiar methods utilizing the wound rotor motor and auxiliary speed regulating equipment. Figure 5 shows in diagrammatic form the general arrangement of machines in the constant horsepower drive.

In the Kraemer system of speed control the secondary of the main drive wound rotor motor is connected to a synchronous converter, which in turn feeds directly into a direct current motor.

In the Constant Horsepower system the direct current motor is solidly coupled to the shaft of the main wound rotor induction motor and in this way the torque available at the shaft increases as the speed decreases, thus resulting in a constant horsepower capacity over the speed range.

In the Constant Torque system, schematically shown in Figure 6, the direct current motor is used to drive a synchronous machine, connected to the same main power supply system which supplies the main drive wound rotor motor, returning slip power to that line. Here the only torque exerted at the main drive shaft is that of the wound rotor motor and, since it is inherently a constant torque machine, the drive will also have that characteristic.

Of the two systems the constant horsepower is by far the most practical one, having been applied to a considerable number of metal rolling mills, and occasionally to other drives, such as large dredge pumps, etc.

Certain types of rolling mills may be designed to turn out different types of products of a more or less special nature. This difference in product generally means different rolling speeds so that the drive must be adaptable to changing requirements. In many such variable speeds mills it will, in general, be desirable to vary the speed inversely as the section rolled, small sections being rolled at high speed and larger sections at lower speeds. Hence, as the speed of the mill decreases, with increasing cross-sectional area of the section rolled, the torque required increases. This increase in torque will be nearly proportional to the decrease in speed, so that the average hp demand of the mill remains practically constant throughout the speed range. Furthermore, there may be conditions where the mill can at times be operated at the full speed of the wound rotor motor, leaving the secondary regulating equipment out of service with resultant higher economy.

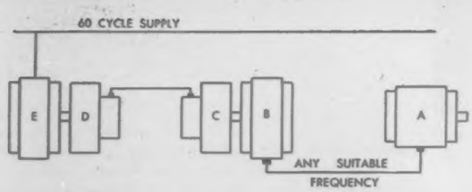
Rating of regulating equipment

The rating of the synchronous converter and direct current motor for a constant horsepower drive, in per cent of the main wound rotor motor, is directly proportional to the reduction in speed, or

$$\text{Hp rating} = \frac{\text{Hp Output} \times \text{Slip}}{100}$$

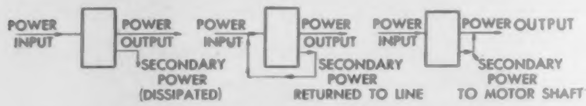
Thus if the drive requires 1000 hp over a speed range of 600 to 300 rpm, the rating of the converter and d-c motor will be based on 500 hp secondary power, with the d-c motor having a base speed of 300 rpm. (This is the same hp as the loss in the secondary of a constant-torque drive motor using secondary resistor for speed regulating). It is obvious that the torque of the 500 hp d-c motor at 300 rpm is the same as for the 1000 hp at 600 rpm and the two torques added together at 300 rpm result in 1000 hp, the same as at 600 rpm.

The rating of the regulating equipment for a constant torque drive is theoretically one-half of that required for a constant hp drive. But it is important to note that as the speed approaches synchronism the ratings approach those of the constant hp drive, as, for example, at 90 per cent speed the constant torque requirement is 9 per cent, for constant hp it is 10 per cent. Hence, the converter and d-c motor must be capable of carrying the same current at that point as for the constant hp drive and must also be designed for the same voltage at the maximum speed reduction. The result is that actually the regulating equipment must be of the same size

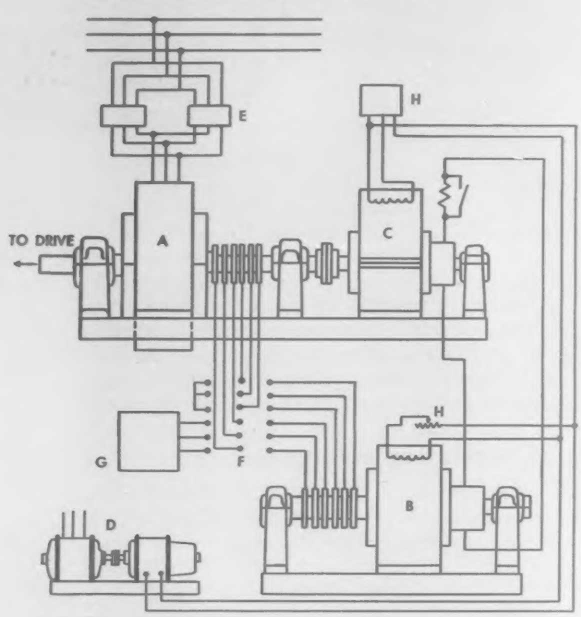


APPROXIMATE machine capacities for large variable frequency drives **(FIG. 3)**

A — Variable speed synchronous or induction motor 100%
B — Synchronous generator 105%
C — D-C motor 110%
D — D-C generator 118%
E — Synchronous motor 126%



DRIVEN LOAD characteristics decide the method of reclaiming secondary power in conventional wound rotor motor, constant torque adjustable speed drive and constant horsepower speed drive. **(FIG. 4)**



CONNECTION DIAGRAM for constant hp Kraemer unit. **(FIG. 5)**

A — Main wound rotor induction motor
B — Synchronous converter, 6-phase
C — D-C speed regulating motor
D — Excitation M-G set
E — Primary oil circuit breakers (forward and reverse)
F — Transfer switch for transfer from starting to regulating
G — Starting duty resistor
H — Speed regulating control (Regulex generator may be used in field of regulating motor C)

as for the constant hp drive, the synchronous generator of the inverted motor-generator set, being the only machine which conforms to the theoretical ratio. For this reason the constant torque Kraemer has very little practical application and it is ordinarily advisable to consider some other form of adjustable speed system for constant torque. Occasionally an application will be found where it may be practicable, for a wide speed range, in the form illustrated by Figure 6.

How it operates

The Kraemer unit is brought up to a full speed as a 3 phase wound rotor induction motor, by means of secondary resistor and usually a full magnetic current limit control. After the induction motor is up to speed, field is applied to the converter and the secondary of the wound rotor motors transferred to that machine.

The speed of the Kraemer unit is then regulated by adjusting the field strength of the d-c motor, any change in field strength directly affecting its counter-emf. This change is reflected in voltage across the synchronous converter and consequently at the collector rings of the wound rotor motor. Such a change in voltage will then cause the induction motor speed to change until a stable condition is reached where a secondary current corresponding to the load can flow. It is clear that the speed will not change widely with load as in the case where secondary resistor is used for speed regulating, since a definite counter-emf is at all times present holding speed regulation with load change within definite limits. Better regulation than is inherent in this system is seldom required in the type of drives to which it is applied, but, if required, can generally be provided by control of the d-c motor field. Normal inherent speed regulation is comparable to that of a d-c drive.

As synchronous speed is approached on the Kraemer unit the secondary voltage and frequency of the induction motor decrease. For this reason the regulating equipment becomes ineffective as full speed is approached with the converter becoming unstable at about 3 or 4 cycles. Thus the practical operating range is up to approximately within 5 per cent of synchronous speed of the induction motor.

At synchronous speed the induction motor secondary voltage would be zero, no current would flow and the motor could develop no torque. Because of this it is not possible to operate a Kraemer unit through synchronous speed, i.e., double range, as can be done in certain other systems, without the use of special equipment to provide current in the rotor circuit of sufficient value to produce the torque necessary to pull the rotor through the synchronous speed point.

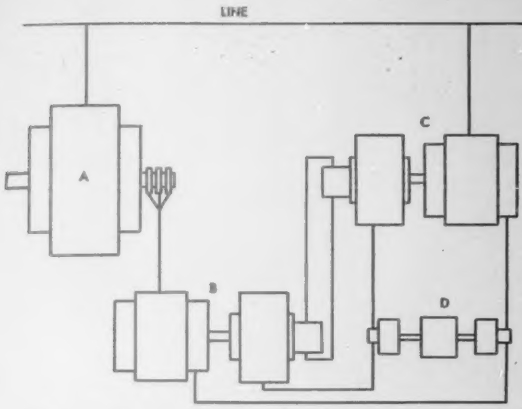
Overall efficiency is good

The overall efficiency of the Kraemer system is good and compares favorably with any other type of adjustable-speed drive. The fact that the auxiliary regulating equipment is of reduced size in general makes for a better overall efficiency than, for example, the direct current drive using motor-generator set and d-c motor. This can be shown by taking a 2000 hp, 300/600 rpm, 600 volt drive as an example.

Assume 2000 hp, 300/600 rpm, d-c motor having a full load efficiency of 92.5 per cent and thus requiring a 1590 kw supporting motor-generator set.

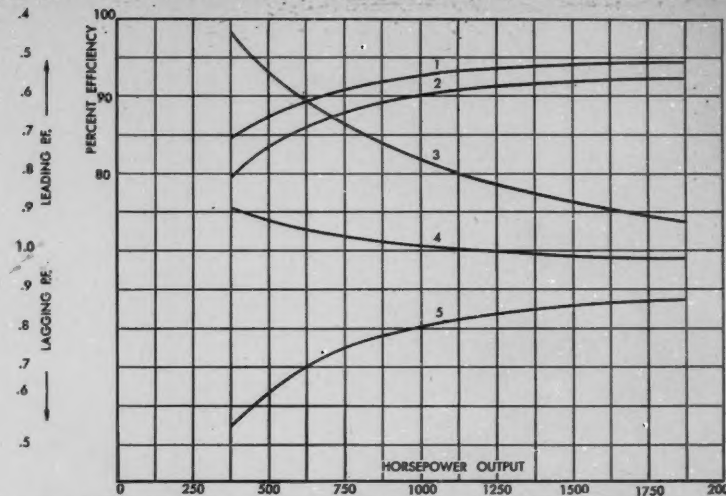
	Normal Efficiencies	HP Loss
M-G Set	90.1	235
D-C Motor	92.5	162
Total Losses		397
Overall Efficiency	83.5%	

In the case of a constant hp Kraemer unit of the same rating and speed range the main induction motor will be rated 2000 hp at 600 rpm, the synchronous converter $\frac{(2000 \times 50\%)}{100\%} =$ 1000 hp or 746 kw and the d-c motor 1000 hp, at 300 rpm. Using typical efficiencies of



CONSTANT TORQUE Kraemer unit for wide speed range uses M-G set in place of synchronous converter. **(FIG. 6)**

A — Main drive wound rotor induction motor
B — Adjustable-speed synchronous M-G set
C — Constant-speed inverted M-G set feeding back into line
D — Excitation M-G set



TYPICAL TEST RESULTS on a 1500 hp 508/257 rpm constant hp Kraemer unit. **(FIG. 7)**

1 — Efficiencies of induction motor alone at full speed
2 — Efficiencies of Kraemer unit only at half speed
3 — Power factor of synchronous converter
4 — Power factor of Kraemer unit induction motor at half speed
5 — Power factor of induction motor operating alone at full speed

the individual machines we then get:

	Normal Efficiencies	Hp Loss
W-R Motor	93.8	132
Converter	94.5	58
D-C Motor	90.0	111
Total Losses		301
Overall Efficiency	87.0%	

What power factor?

The power factor at the terminals of the Kraemer unit induction motor will be a function dependent upon the combination of machines used. The larger the induction motor rating and the higher its basic speed, the higher will be its power factor. Likewise, the greater the speed reduction the larger will be the synchronous converter and, consequently, the greater will be its influence on the unit power factor. Since the a-c and d-c voltages in a converter bear a fixed ratio and are fixed by the voltages of the secondary of the wound rotor motor and the excitation of the d-c motor, the converter field excitation affects only its power factor. Ordinarily the converter is designed for unity power factor at full load and hence with fixed field excitation the power factor will be leading for fractional loads.

Figure 7 is indicative of the power factor relations of a constant hp Kraemer unit of average size and speed; at full speed operation as a straight induction motor and at half speed as a Kraemer unit. It will be seen that at half speed the power factor at full load is approximately unity. For other speeds in the range, between half and full speeds, the power factor will vary between the two sets of values indicated.

Of course, the lower the basic induction motor speed the lower its power factor will be and for that reason the full load Kraemer unit power factor at the lowest regulating speed will not necessarily be as high as unity. However, in any case, the power factor at regulating speeds will be materially better than for the induction motor alone and particularly so at fractional loads.

System pros and cons

One of the main advantages of the Kraemer system, both from the standpoints of manufacturing and operating, is the fact that relatively standard machines can be used. The main induction motor is a standard machine except for the fact that the rotor winding is usually brought out to six collector rings in order to take full advantage of the 6-phase converter.

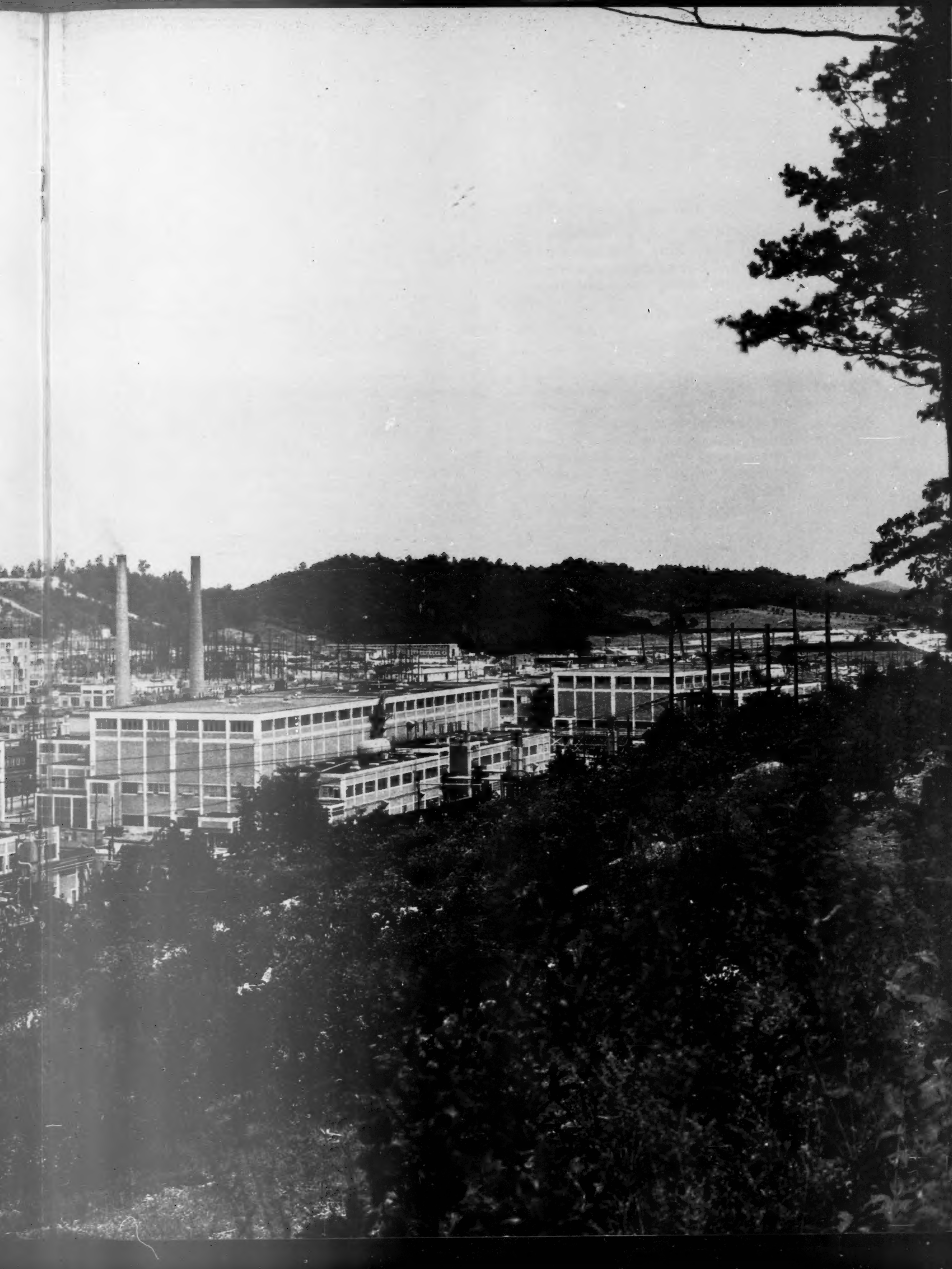
The synchronous converter is usually a standard 25-cycle frame, for as a rule it is usually applied to 60 or 50 cycle motors where with a 50 per cent maximum speed reduction the secondary frequency is 30 or 25 cycles respectively. Wherever possible, the induction motor rotor windings will be designed for a secondary voltage which will permit the use of standard 250 or 600 volt d-c machines. It will be obvious that the a-c voltage at the converter rings will be directly proportional to the slip of the induction motor and hence for a constant hp the converter will have practically constant current.

The speed-regulating d-c motor is also built on standard frames and requires little change in detail design from that used for a straight d-c drive.

Use of the Kraemer system is limited to the higher standard commercial frequencies of 60 or 50 cycles for the reason that if it is attempted to apply it to a lower frequency, such as 25 cycle, the converter would become unduly large and costly. Conversely, the converter limits the speed reduction to 50 per cent on 60 cycle system since the converters then operating at 30 cycles reach the highest practicable operating speeds. On a 50-cycle system it is therefore possible to attain a 60 per cent speed reduction with a converter frequency of 30 cycles.

The control is relatively simple and operation involves no difficulties in training of operating personnel since the machines involved are of such standard nature as to be familiar to the majority of mill operators. And, because of the standard nature of the machines, unusual maintenance problems are not likely to arise.

ELECTRO-MAGNETIC separation of U-235 was done at the huge plant at Oak Ridge, Tennessee, shown on following pages in one of the most striking pictures of the entire atomic bomb project. To this plant were shipped many huge electro-magnets and motor-generator sets from Allis-Chalmers, one of the very largest of the suppliers of equipment. Over 12,000,000 pounds of silver alone were used for conductor material in the giant electro-magnets.



Preferred Numbers, ... PLEASE!

NOT a discourse on "lucky numbers" — but a thought-provoking discussion of a highly important but seldom-considered problem of users, designers, and builders of equipment.

R. O. TJENSVOLD
Industrial Relations Division
Allis-Chalmers Mfg. Co.

IN considering the hundreds of everyday items we buy that come in a range of sizes — from copper wire to cans of paint to motors — it would *appear* that our buying habits have been standardized by the product sizes available on the dealer's shelf. The situation in many cases is actually just the opposite — standard sizes which satisfy recognized and analyzed needs are determined by application of the system of preferred numbers.

According to the psychological reasoning on which preferred numbers are based, the human mind naturally accepts or gravitates toward a geometrical progression in preference to an arithmetical progression in determining a series of graded sizes. Research in this field has shown that if our accepted standard sizes (as of bolts or wire or pipe) were plotted as ordinates against serial numbers as abscissas, all would be along curves that are roughly parabolic in outline. Outstanding French and German researchers for more than three decades advanced the argument that we may as well admit the existence of this "normal" preference and accept geometric progression.

In working out a series (such as sizes or dimensions) between one and 100, for example, the engineer could choose equal steps of one each. Then the difference between the first two steps (1 and 2) would be 100 per cent, while the difference between the last two steps (99 and 100) would be only one per cent. The engineer, instead, turns to geometric progression. His average for the above series of steps from one to 100 would not need to be the arithmetical average of 50½, but might readily be the more reasonable geometric mean of 10. These relationships are, to him, more "natural."

Industries and standardizing agencies in European countries adopted industrial preferred numbers series long before engineers in the United States. Two reasons account for the lag in the more general adoption of preferred numbers. One is the small amount of publicity given this important advance, since the subject is not even discussed in most engineering courses. The other reason is that wherever the subject has received attention, preferred numbers were portrayed as difficult to understand. Quite the opposite is true.

Systematic application of geometric progression to number series for engineering use waited until early in the twentieth century for recognition. One of the earliest accounts of how preferred numbers could be applied is to be found in an article by Reinhold Rudenberg in the June, 1918, issue of *Verein Deutscher Ingenieure* in which he developed a "series" remarkably akin to that adopted by the American Standards Association eighteen years later. The German *Modellreihen* in the "10-series" was:

10 12.5 16 20 25 32 40 50 63 80 100

The ASA 10-series is:

10 12.5 16 20 25 31.5 40 50 63 80 100

The only variation between the two is the difference between 32 and 31.5. Many designers who believe that every fourth step should double would hold that only the first series is nearly correct. Actually, the difference, which is more apparent than real, is a product of "rounding," a process which has been approved by the American Standards Association.

In 1934 the first draft of the proposed American standard on preferred numbers was published for general criticism and comment, the final draft — a slightly modified version of the original — was unanimously approved by autonomous Sectional Committee on Preferred Numbers of the American Standards Association in 1935, and the ASA approved this proposed American Standard Z-17, on April 14, 1936, subsequently publishing the standard.

The American Standards Association's definition of preferred numbers is:

> Preferred numbers are series of numbers selected to be used for standardization purposes in preference to any other numbers. Their use will lead to simplified practice and they should, therefore, be employed whenever possible for individual standard sizes and ratings, or for a series thereof, in applications similar to the following:
>
> Important or characteristic linear dimensions, such as diameters and lengths.
>
> Areas, volumes, weights, and capacities.
>
> Ratings of machinery and apparatus in horsepower, kilowatts, kilovolts-amperes, voltages, current, inductances, capacitances, speeds, power-factors, pressures, heat units, temperatures, gas or liquid-flow units, weight-handling capacities, etc.
>
> Characteristic ratios of figures for all kinds of units.

How theory works

Simply explained, preferred numbers are based on geometric progression, where a series of successive terms are found by multiplying by the same number, called the "common ratio." Thus:

In 2, 10, 50, 250, the common ratio is 5. If the first term in a geometric progression were "a," and the common

ratio "r," the number of terms "n" and the last term "n-1," the formula could be expressed to show successive terms thus:

1st	2nd	3rd......	nth
a	ar	ar^2	ar^{n-1}

To evolve a common ratio, then, the formula would become:

$$\sqrt[n-1]{\frac{ar^{n-1}}{a}}$$

This has been done in the case of preferred numbers. Using 10 as the first number of the series, the other theoretically exact numbers of any series are obtained by multiplying or dividing the first number by the constant factor applying to that particular series and repeating this operation, in sequence, with each resultant number. The basic factors are established as follows:

for the 5 series $\sqrt[5]{10}$ or 1.5849

for the 10 series $\sqrt[10]{10}$ or 1.2589

for the 20 series $\sqrt[20]{10}$ or 1.1220

for the 40 series $\sqrt[40]{10}$ or 1.0592

Because the basic advantage of the preferred numbers system is that its construction uses a geometric series with each number larger than the preceding one by a given percentage, the use of series other than those accepted as standard should be avoided. Says ASA, "In order to further standardization, it is essential that the Preferred Numbers given in the tables be used."

The basic preferred numbers as established by the American Standards Association are listed in Table I with recommendations that for any given line or group of materials "the same series should be adhered to over as wide a range as possible, but a change from one series to another is frequently necessary in order to obtain the maximum utility and economy in the particular case involved." For example, the numbers in the 5-series should be given preference over the 10-series and so on. However, if the integration of an existing line of products with a preferred numbers series demands it, a manufacturer or designer may have the first half of his preferred sizes in the 10-series and the second half in the 20-series. Obviously, he is adhering to the principles involved if he follows the accepted preferred numbers and makes whatever deviations are necessary consistent with the system.

In some instances the whole numbers or decimal series may be inadequate as with some stock materials and hardware where practice dictates small sizes of the item. Here the fractional series in sizes from 1/8 to 40 may be used with its variations. The basic fractional series (Table II) is used only in the United States since other countries do not deviate from the decimal system and most of them use the metric scales.

The American Standard Preferred Numbers provides for the conversion of inches to centimeters, since the conversion factor of 2.54 for changing inches to centimeters is approximately a Preferred Number. When converting inch values of the decimal Preferred Numbers system into metric units, the results will again be approximate Preferred Numbers (within 1.6 per cent). This approximation in most cases is satisfactory. With the fractional system the discrepancies are much greater (up to about 5 per cent), and standardization of dimensions that may become important internationally should preferably use the decimal series of Preferred Numbers.

Tables III, IV, V, and VI are principally supplemental series. From these practically every necessary combination can be built up by means of cross-usage or division or multiplication of the standard series.

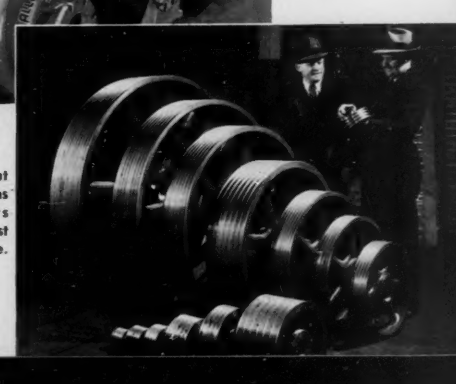
The system, therefore, is a simple means of arriving at a minimum necessary number of sizes for any given device which will meet its service requirements adequately. A further value of preferred numbers is that they provide for more sizes to be added logically if the original range of the first series is incomplete.

Applications of preferred numbers

There are varying degrees of applicability of standards as well as numerous features upon which to standardize, but "a standard reaches its highest degree of effectiveness when its requirements are stated in terms of measurement."

The standard of performance, while specifying requirements, leaves complete freedom in the choice of the means by which these requirements shall be met. The unit of measurement serves to coordinate the factors required for attaining a performance, but is independent of the question what the actual values of these factors should be. By using preferred numbers, rational methods are applied to this problem of advance selection of the right size for manufactured items. Standardization, it is agreed, can be justified in industry only if it brings about economies without interfering with progress but present practices for arriving at any standard are generally so cumbersome and time-consuming that full value of the inherent economies is not always realized. This is as true of preferred numbers as it is of other types of standards.

Between development of the first electric motor and adoption of the preferred numbers system every motor builder had complete freedom of choice of ratings, which led to an industrial confusion not frequently paralleled. Had one manufacturer established his own standards with motors of 20, 25, 35, 50, and 75 horsepower, and another with horsepower ratings of 20, 25, 30, 50, 60, and 75, the former would soon introduce a 30 hp number to meet the competition. Customers



PUMPS and sheaves are but two of the countless items which industrial users purchase to meet their first requirement of suitable size.

TABLE I[1]

Basic Preferred Numbers—Decimal Series (10 to 100)

5 Series 60% Steps	10 Series 25% Steps	20 Series 12% Steps	40 Series 6% Steps
10	10	10	10
			10.6
		11.2	11.2
			11.8
	12.5	12.5	12.5
			13.2
		14	14
			15
16	16	16	16
			17
		18	18
			19
	20	20	20
			21.2
		22.4	22.4
			23.6
25	25	25	25
			26.5
		28	28
			30
	31.5	31.5	31.5
			33.5
		35.5	35.5
			37.5
40	40	40	40
			42.5
		45	45
			47.5
	50	50	50
			53
		56	56
			60
63	63	63	63
			67
		71	71
			75
	80	80	80
			85
		90	90
			95

Preferred numbers below 10 are formed by dividing the numbers between 10 and 100 by 10, 100, etc.

Preferred numbers above 100 are correspondingly formed by multiplying the numbers between 10 and 100 by 10, 100, etc.

Percentage steps in headings are approximate averages.

TABLE II

Preferred Numbers—Basic Fractional Series

1/8 to 1				1 to 10				10 to 40			
5 Series 60% Steps	10 Series 25% Steps	20 Series 12% Steps	40 Series 6% Steps	5 Series 60% Steps	10 Series 25% Steps	20 Series 12% Steps	40 Series 6% Steps	5 Series 60% Steps	10 Series 25% Steps	20 Series 12% Steps	40 Series 6% Steps
				1	1	1	1	10	10	10	10
							1 1/16				10 1/2
						1 1/8	1 1/8			11	11
							1 3/16				11 1/2
	1/8	1/8			1 1/4	1 1/4	1 1/4		12	12	12
							1 5/16				13
		9/64				1 3/8	1 3/8			14	14
							1 7/16				15
5/32	5/32	5/32		1 1/2	1 1/2	1 1/2	1 1/2	16	16	16	16
							1 5/8				17
		11/64				1 3/4	1 3/4			18	18
							1 7/8				19
	3/16	3/16	3/16		2	2	2		20	20	20
			13/64				2 1/8				21
		7/32	7/32			2 1/4	2 1/4			22	22
			15/64				2 3/8				23
1/4	1/4	1/4	1/4	2 1/2	2 1/2	2 1/2	2 1/2	24	24	24	24
			17/64				2 5/8				26
		9/32	9/32			2 3/4	2 3/4			28	28
			19/64				2 7/8				30
	5/16	5/16	5/16		3	3	3		32	32	32
			21/64				3 1/4				34
		11/32	11/32			3 1/2	3 1/2			36	36
			23/64				3 3/4				38
3/8	3/8	3/8	3/8	4	4	4	4	40	40	40	40
			13/32				4 1/4				
		7/16	7/16			4 1/2	4 1/2				
			15/32				4 3/4				
	1/2	1/2	1/2		5	5	5				
			17/32				5 1/4				
		9/16	9/16			5 1/2	5 1/2				
			19/32				5 3/4				
5/8	5/8	5/8	5/8	6	6	6	6				
			21/32				6 1/2				
		11/16	11/16			7	7				
			23/32				7 1/2				
	3/4	3/4	3/4		8	8	8				
			13/16				8 1/2				
		7/8	7/8			9	9				
			15/16				9 1/2				

Above 40 the fractional preferred numbers are the same as the decimal preferred numbers, see Table I.

Below 1/8 the decimal series will be used.

Below 3/16 the steps of the 40 series are omitted as finer gradations will seldom be used.

The basic preferred numbers system, being an international system, is based on the use of decimals. But as the use of fractions has become so thoroughly established in the countries using the inch system as the unit of measurement, it was considered advisable by the American committee to devise a fractional system of Preferred Numbers, over the range between 1/8 inch to 40 inches, over which the use of fractions is most customary.

In order to make this system conform to well-established practices, the selected figures do not conform as closely to the theoretical values as the figures in the decimal system, the discrepancy being as much as 4 to 6 per cent in some cases. The maximum difference between values of the decimal and corresponding fractional system is 6.3 per cent.

The use of the fractional system should be restricted to linear dimensions in inches where fractions are in common use and where therefore the decimal system is impractical. Percentage figures in headings are approximate averages.

would confuse the issue by asking for sizes not found in either company's series, as 33 or 55 hp.

The man who paid the bill for this lack of system was the customer. Standardization's major sales point is the savings inherent in standard sizes which can be mass-produced. Competition in the open market eventually forced the adoption of some types of standards, although it took nearly 30 years for electric motor manufacturers to develop and accept size standards. Similar chaos prevailed for practically every type of apparatus, such as generators, transformers, controllers, etc.

In a new industry, also, it is difficult to establish standards since there are few central agencies for clearing information or any joint action on the part of the manufacturers themselves. Much time and readjustment is often necessary to accept standards and put them into operation. General acceptance of preferred number standardization would help to eliminate such wastefulness, since tentative ratings would follow similar lines with all manufacturers.

Standardization of electric motor sizes, referred to above, presents no particular technical difficulties. Table VII shows the present accepted standard ratings between 1 and 100 hp and also the nearest figures from the 5-series (up to 16 hp) and the 10-series (from 20 hp upward).

TABLE VII

MOTOR HORSEPOWER RATINGS

Present Standards	5-Series	10-Series
1	1	..
1.5	1.6	..
2	2.5	..
3	4.0	..
5	..	..
7.5	6.3	..
10	10	..
15	16	..
20	..	20
25	..	25
30	..	31.5
40	..	40
50	..	50
60	..	63
75	..	80
100	..	100

The practical mechanic may feel that the whole subject of preferred numbers is just theory and that we can accomplish just as much by allowing each manufacturer to work out his own standards. After all, he will point out, hasn't the Brown and Sharpe wire gauge been in use for 80 years?

It is true that this pre-dates the standard preferred numbers system by a half century in this country. It is likewise

TABLES III AND IV
BASIC PREFERRED NUMBERS—80 SERIES

Series					TABLE III Decimal Series 10 to 100		TABLE IV Fractional Series 3/8 to 40 (Only for dimensions in inches)			
5	10	20	40	80	10	40	3/8	1 1/2	6	24
				80	10.3	41.2	25/64	1 9/16	6 1/4	25
			40	80	10.6	42.5	13/32	1 5/8	6 1/2	26
				80	10.9	43.7	27/64	1 11/16	6 3/4	27
		20	40	80	11.2	45	7/16	1 3/4	7	28
				80	11.5	46.2	29/64	1 13/16	7 1/4	29
			40	80	11.8	47.5	15/32	1 7/8	7 1/2	30
				80	12.1	48.7	31/64	1 15/16	7 3/4	31
	10	20	40	80	12.5	50	1/2	2	8	32
				80	12.8	51.5	33/64	2 1/16	8 1/4	33
			40	80	13.2	53	17/32	2 1/8	8 1/2	34
				80	13.6	54.5	35/64	2 3/16	8 3/4	35
		20	40	80	14	56	9/16	2 1/4	9	36
				80	14.5	58	37/64	2 5/16	9 1/4	37
			40	80	15	60	19/32	2 3/8	9 1/2	38
				80	15.5	61.5	39/64	2 7/16	9 3/4	39
5	10	20	40	80	16	63	5/8	2 1/2	10	40
				80	16.5	65	41/64	2 9/16	10 1/4	
			40	80	17	67	21/32	2 5/8	10 1/2	
				80	17.5	69	43/64	2 1/16	10 3/4	
		20	40	80	18	71	11/16	2 3/4	11	
				80	18.5	73	45/64	2 3/16	11 1/4	
			40	80	19	75	23/32	2 7/8	11 1/2	
				80	19.5	77.5	47/64	2 15/16	11 3/4	
	10	20	40	80	20	80	3/4	3	12	
				80	20.6	82.5	25/32	3 1/8	12 1/2	
			40	80	21.2	85	13/16	3 1/4	13	
				80	21.8	87.5	27/32	3 3/8	13 1/2	
		20	40	80	22.4	90	7/8	3 1/2	14	
				80	23	92.5	29/32	3 5/8	14 1/2	
			40	80	23.6	95	15/16	3 3/4	15	
				80	24.3	97.5	31/32	3 7/8	15 1/2	
5	10	20	40	80	25		1	4	16	
				80	25.7		1 1/32	4 1/8	16 1/2	
			40	80	26.5		1 1/16	4 1/4	17	
				80	27.2		1 3/32	4 3/8	17 1/2	
		20	40	80	28		1 1/8	4 1/2	18	
				80	29		1 5/32	4 5/8	18 1/2	
			40	80	30		1 3/16	4 3/4	19	
				80	30.7		1 7/32	4 7/8	19 1/2	
	10	20	40	80	31.5		1 1/4	5	20	
				80	32.5		1 9/32	5 1/8	20 1/2	
			40	80	33.5		1 5/16	5 1/4	21	
				80	34.5		1 11/32	5 3/8	21 1/2	
		20	40	80	35.5		1 3/8	5 1/2	22	
				80	36.5		1 13/32	5 5/8	22 1/2	
			40	80	37.5		1 7/16	5 3/4	23	
				80	38.7		1 15/32	5 7/8	23 1/2	

While there are few applications requiring steps smaller than the six per cent steps of the 40 series such cases may nevertheless occur at times. Therefore the American Committee has adopted an 80 series, both decimal and fractional, as indicated in Tables III and IV. The numbers of this series should also be useful in many cases in actual practice where it is necessary to standardize two values which should be rather close together and where a difference of three per cent is suitable. One of the values can be chosen from one of the coarser series and the other can be the value of the 80 series immediately following.

Steps between numbers in Tables III and IV increase approximately three per cent on an average.

TABLES V AND VI
SUPPLEMENTARY SERIES OF PREFERRED NUMBERS

TABLE V
Decimal Series—1 to 1000

5/2 Series 150% Steps	5/3 Series 300% Steps	10/3 Series 100% Steps	20/3 Series 40% Steps	40/3 Series 18% Steps
1	1	1	1	1
2.5				1.18
6.3			1.4	1.4
16				1.7
40		2	2	2
100				2.36
250			2.8	2.8
630				3.35
	4	4	4	4
				4.75
			5.6	5.6
				6.7
		8	8	8
				9.5
			11.2	11.2
				13.2
	16	16	16	16
				19
			22.4	22.4
				26.5
		31.5	31.5	31.5
				37.5
			45	45
				53
	63	63	63	63
				75
			90	90
				106
		125	125	125
				150
			180	180
				212
	250	250	250	250
				300
			355	355
				425
		500	500	500
				600
			710	710
				850

Preferred numbers below 1 and above 1000 are formed by dividing the numbers between 1 and 1000 by 1000.

Preferred numbers above 1000 are correspondingly formed by multiplying the numbers between 1 and 1000 by 1000.

TABLE VI
Fractional Series—1/8 to 40

5/2 Series 150% Steps	5/3 Series 300% Steps	10/3 Series 100% Steps	20/3 Series 40% Steps	40/3 Series 18% Steps
		1/8	1/8	
			11/64	
				13/64
	1/4	1/4	1/4	1/4
				19/64
			11/32	11/32
				13/32
		1/2	1/2	1/2
				19/32
5/32			11/16	11/16
3/8				13/16
1	1	1	1	1
2 1/2				1 3/16
6			1 3/8	1 3/8
16				1 5/8
40		2	2	2
				2 3/8
			2 3/4	2 3/4
				3 1/4
	4	4	4	4
				4 3/4
			5 1/2	5 1/2
				6 1/2
		8	8	8
				9 1/2
			11	11
				13
	16	16	16	16
				19
			22	22
				26
		32	32	32
				38

Supplementary series are selected from the basic series and are used where percentage steps above 60 or between 60 and 25 or between 25 and 12 are necessary for some justifiable reasons.

Where it is desirable to have a nine per cent increase in steps, such a series may be constructed by using every third step in the 80 series.

Percentage figures in headings are approximate averages.

true, however, that the real basis of Brown and Sharpe size variations is *geometric progression,* giving each size a diameter greater than the preceding one by a constant percentage.

In fact the popularity enjoyed by this gauge is due to the utility inherent in preferred numbers, a system of standards of which Brown and Sharpe was—perhaps unintentionally—an advocate.

Simplicity is keynote

Thus we see that "preferred numbers" are simply groups of numbers which should be used in preference to any others whenever a standardization of ratings, dimensions, or what not is desirable.

Most of the objections raised against the introduction of preferred numbers into industry have been based on misconceptions of their nature. In cases where immediate application is not practical for reasons of economy, it is often possible to make use of some of the principles of preferred numbers. In cases where product revisions are taking place, or where new systems are being installed, preferred numbers series can be followed without penalty or difficulty, and at considerable economical savings. It is obvious that if certain numerical values are accepted as standard and preferred for use wherever they will meet the requirements at least as well as arbitrary choices, they should be used. Then if similar choices must be made in the future they can be readily integrated with the former choice by reason of the existing logical relationships. Many expanding fields would benefit by the universal adoption of preferred numbers now so that future developments may fall into the same pattern. Mechanical and electrical ratings, sizes of round cold roll steel, hardness or strength standards and refrigerator capacities are but a few of the objects or properties already standardized by use of the preferred numbers system.

With some industrial equipment where it is possible to use preferred numbers for a variety of purposes as ratings, speeds, volume, etc., interrelationship of such factors will create problems. For example, a container may be standardized for some use, with the volume and two of the dimensions being preferred numbers. But the third dimension and the weight of the material used could not be part of a preferred number series because of a definite relationship that must exist between all the factors. Questions like these must be settled on individual merits — such as common practice or end use determinations.

Above all, it should be pointed out that while preferred numbers should be used very extensively, considerations of *utility, economies,* and especially *common sense,* must govern their application.

1. All tables reprinted from Section Z-17, American Standards Association standards

The Sinusoidal D-C Positioner

CHARLES R. MIKOLIC
Development Engineer, Control Section
Allis-Chalmers Mfg. Co.

Restricted during the war for marine use . . . details are disclosed here of a new remote control operating from either a-c or d-c lines.

THE two-phase d-c sinusoidal system was originally developed to provide accurate positioning devices for a number of d-c remote control applications. Ten years ago, original laboratory tests demonstrated certain inherent functional advantages of the new equipment over existing a-c selsyns. Since then, thousands of commercial and war installations have confirmed the existence of a number of unique features, of which the following are especially noteworthy:

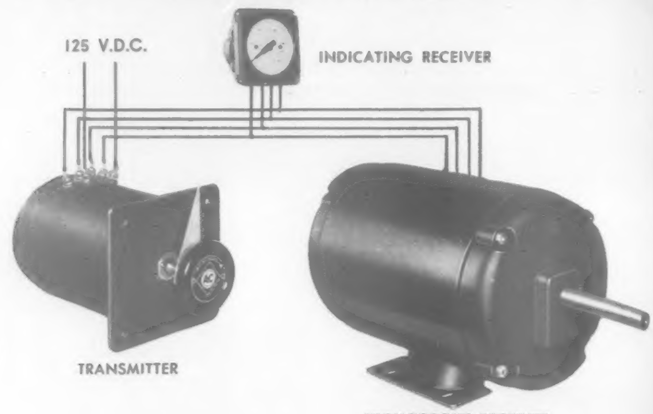
1. Complete elimination of "hunting."
2. Absence of any torque reaction on transmitter.
3. No inductive circuit reactance.
4. Availability of system torque amplification.
5. Close limitation of circuit power requirements.
6. Possibility of eliminating all rotor circuits.
7. Invariable tendency of system to return to set position following intermittent power failures in circuit.

Demands of the war emergency period brought about rapid development and improvement of these indicating and control devices as well as manufacturing processes. As a result, existing standards of accuracy and performance are comparable with those of any other electrical system.

Method of operation

The circuit used in the operation of this system is similar to that of any continuous potentiometer bridge circuit. The resistance bridge of the transmitter is energized through fixed connections to the d-c supply source and the receiver phase circuit voltages and currents are varied by angular displacement of the roller brushes on the contact surface of the element. Figure 2 shows an elementary schematic diagram of the circuit.

In the normal operation of this system, if a zero reference point is set at the transmitter position which produces a maximum current through one receiver phase and zero current through the other, the functioning of the system may be explained in the following manner. Displacement of the transmitter from the zero position in either direction will cause the current to decrease in the maximum phase and to increase in the phase at zero potential, with its polarity determined by the direction of rotation. The relationship of the changes in the phase currents is fixed in all positions and the proportional changes are sinusoidal functions of the transmitter angle of displacement from zero. This variation combined with the effect of sinusoidal windings in the receiver stator produces a resultant magnetic field rotating in step with the transmitter position. This is illustrated in vector diagram, Figure 3. Since the phase circuit potentials and currents are sinusoidal the receiver power input remains constant throughout the operating range of the equipment. Figure 4 illustrates the sinusoidal variation of the receiver phase currents and voltages.



THREE BASIC ELEMENTS in a typical Sinusoidal D-C Positioner are shown here. The receiver shown uses a permanent magnet rotor. **(FIG. 1)**

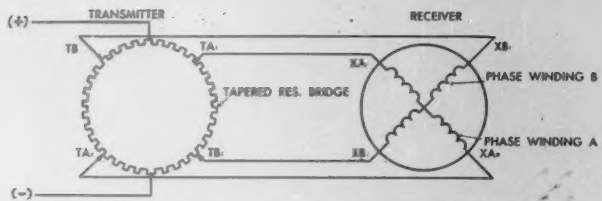
From the foregoing discussion it is apparent that the available receiver torque at any rotor position, within its maximum pull-out value, is entirely independent of transmitter position, being determined solely by design constants. Displacement of the receiver rotor from its normal alignment with stator magnetic axis creates the operating torque, proportional to the displacement, without a reaction on the electrical circuit of the system. Thus the torque required to operate a transmitter is a function of its mechanical design and is entirely independent of the torque available at the receivers which it operates. Torque amplification ratios of several hundred to one are feasible in this system. An example of torque amplification is the use of a small transmitter requiring less than one-half pound-inch operating torque to control a large receiver producing a maximum static torque of 360 pound-inches.

How mechanical construction differs

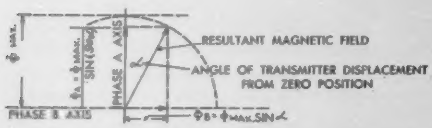
The main structural difference between sinusoidal d-c equipment and other positioning devices lies in the construction of the receiver stator and in the tapered resistance element of the transmitter.

The receiver is composed of, essentially, the stator assembly, the rotor and the bearing assemblies. The stator assembly consists of two concentric, sinusoidally wound phase windings set in quadrature in a closed slot solid iron core, and encased by the solid iron outer shell. Special magnetic iron is required for both core and shell and close fit tolerances are maintained in assembly to assure uniform magnetic characteristics.

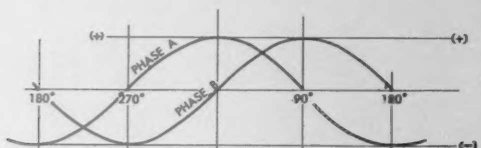
The rotor may be one of four types which include: (a) permanent magnet, (b) plain iron, (c) energized fixed field, and (d) wound armature with two or more independent windings for special applications. The permanent magnet rotor, most



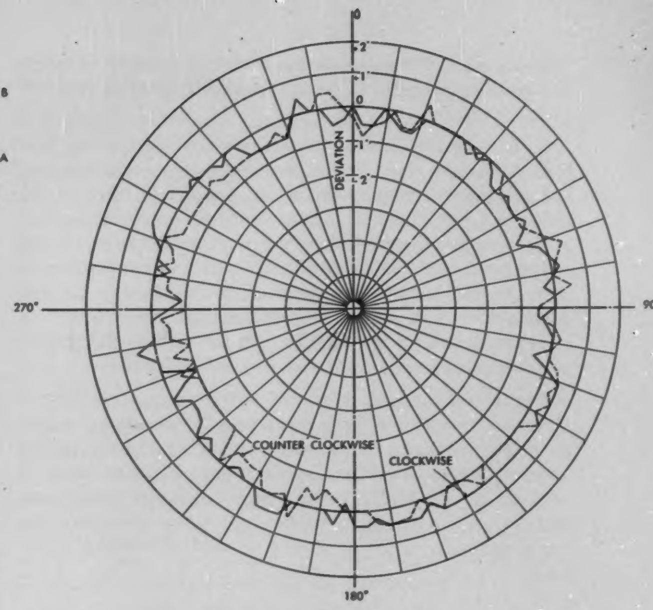
Elementary Schematic Diagram of System (FIG. 2)



Vector Diagram of Receiver Flux (FIG. 3)



Sinusoidal Phase E.M.F. Distribution (FIG. 4)



Typical Positioning Accuracy Curve
120 V. D-C Remote Indicator System (FIG. 5)

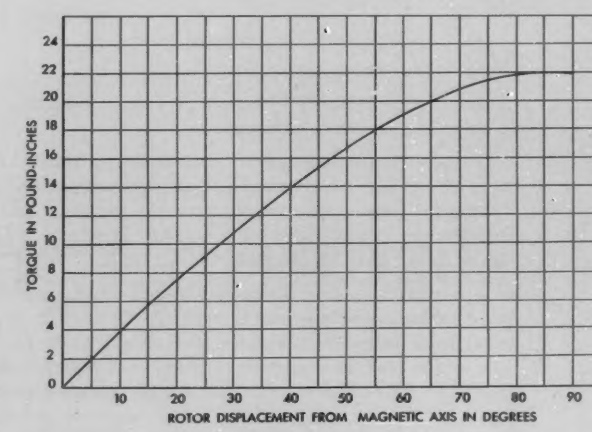
commonly used, consists simply of a two-pole permanent magnet rigidly mounted on the rotor shaft. The energized fixed field and the plain iron rotors are similar in construction with the exception of a single circuit winding used on the former. This winding is energized at a fixed potential during normal operation of the unit. The wound armature rotor may have two or more separate windings which can be used to control independent functions in special control applications.

Processed instrument type bearings are used in the bearing housing assemblies of receivers for indicator applications, to increase sensitivity of the units by reduction of mechanical friction. Sleeve type bearings may be used in units for general control applications.

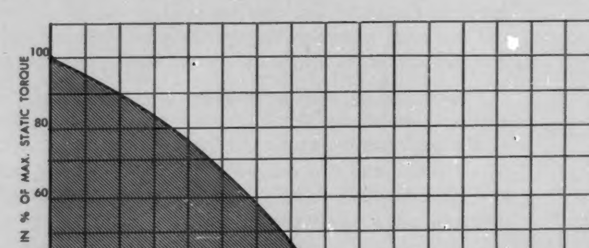
Structural design of the transmitter varies with the specific application. Two general types are commonly used, one type for indicator applications and another for ordinary control functions.

Proper positioning in indicator systems normally requires smoothness of operation and relatively high accuracy. In a d-c system both factors are dependent upon the uniformity and relative magnitude of the step increments. For this reason it is desirable that as many steps as possible be used and that step increments be made as small as possible. Practical considerations demand that the step increment be considerably smaller than that required for the minimum specified accuracy of the system.

The tapered resistance element used in this transmitter is wound on a special cylindrical form with a sufficient number of turns to provide a theoretical positioning accuracy several times that normally specified for high accuracy indicator units. Electrical contact between the rotating element and the transmitter terminals is made through four roller brushes mounted, 90 degrees apart, on a stationary brush base. Diametrically opposite rollers are the terminals of the respective receiver

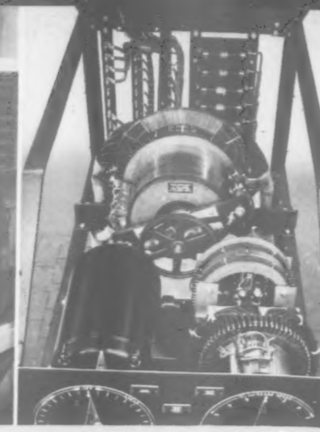


Typical Static-Torque Curve
Standard 50-watt, 120 V. D-C Receiver (FIG. 6)

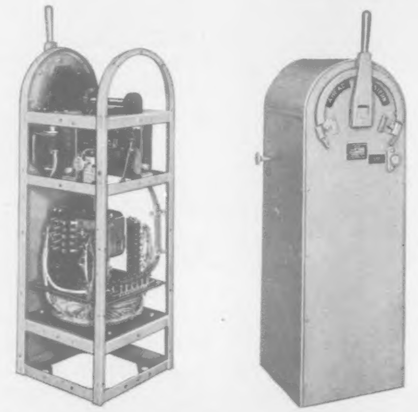


Typical Speed Torque Curve
Sinusoidal D-C Positioner System (FIG. 7)

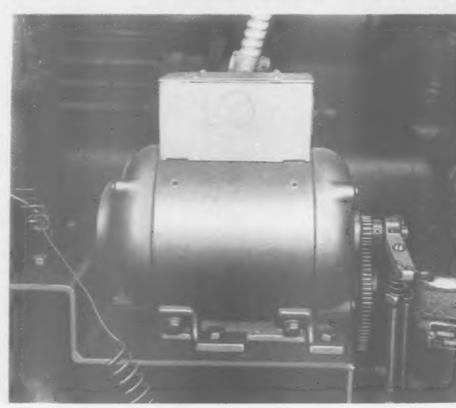
ENGINE ROOM CONTROL STAND houses all speed control for a seagoing tug. Operator is varying combined field — speed control. **(FIG. 8)**



INTERIOR VIEW of control sta... with positioner receiver (left) and engine governor transmitter (right center). Thousands of these marine positioner systems were built. **(FIG. 9)**



PILOT HOUSE CONTROL STAND with transmitter mounted vertically in center. This transmitter energizes receiver in Fig. 9 which in turn controls generator field as well as generator speed through another transmitter and receiver system. Torque amplification is important advantage here. **(FIG. 10)**



SMALL RECEIVER used as a positioner for speed control on a diesel-electric switch engine. Similar units have been operating several years trouble-free. **(FIG. 11)**

phase circuits. D-c power is supplied to the element by means of two sliding brushes in contact with collector rings mounted on the brush base.

Control transmitters use the same circuit design but generally have fewer and larger positioning steps. The mechanical construction is normally more rugged than that of the indicator type. The resistance element may consist of a group of fixed tapped resistors, connected to contact segments mounted on stationary rings. Brushes on rotating contact arms complete the circuit from receivers to the bridge through flexible leads. This type of unit, although not suitable for continuous rotation applications, can be readily modified to perform many complicated remote control functions.

Control transmitters for continuous rotation are similar in construction to the foregoing type with the exception that the flexible leads and brush arms are replaced by a contact surface plate on which are mounted four collector rings, in addition to the bridge contact ring. External circuit connections are completed by means of a rotary short-circuiting brush assembly, which eliminates external connections to the rotor.

What design data required?

The important data required in the selection of remote positioning devices for specific control or indicator applications include:

(a) The torque characteristics of the system.
(b) The positioning accuracy.
(c) Power requirements.
(d) Mechanical requirements.

Torque characteristics of the receiver are of prime importance in remote control applications. The maximum static (pull-out) torque, the operating torque gradient, and the speed-torque characteristics of a receiver determine its suitability for a specific application.

The maximum static (pull-out) torque of the receiver is the maximum available torque without slipping of the receiver rotor with the transmitter fixed in any given position. The torque gradient is the rate of change in torque per degree change in rotor deflection from its normal operating position. Figure 6 shows a typical static torque curve of a receiver. The speed torque characteristic of a receiver defines the change in its available torque with respect to the angular velocity of its rotor in the range from zero to no-load pull-out speed of the unit. It is represented graphically by a curve, illustrated in Figure 7. The area bounded by the coordinate axes and the curve represents the operating range of the unit and is a measure of its utility for remote torque applications.

Smoothness as well as accuracy of positioning in a d-c system is primarily determined by the relative magnitude of the step increments on the resistance bridge. As mentioned previously, it is necessary that the number of steps be as large as possible, and the increment as small as possible for optimum operating characteristics.

Load determines rotor lag

Positioning characteristics of control receivers under load conditions are similar to indicator characteristics with the exception that the normal variation between the forward and reverse positioning curves is increased by the amount of angular displacement of the rotor necessary to provide the operating torque.

Positioning accuracy of a system is generally designated graphically by a curve showing the receiver deviation from the transmitter position over the operating range of the system. Figure 5 shows a typical positioning curve of the d-c remote indicator system.

Approximately 40 per cent of the power required in the d-c sinusoidal system is consumed in the transmitted circuit and the balance in the receivers. As noted previously, receiver input remains constant throughout operating range, regardless of load conditions, while transmitter power is subject to about 15 per cent periodic variation due to the nature of bridge circuit. System demands range from six watts for a simple indicator-transmitter circuit to 500 watts or more for large, high-torque control systems.

Commercial applications are many

Applications of the d-c sinusoidal positioning system may be grouped into three general classes:

1. Remote indicator systems.
2. Manual remote control systems.
3. Automatic and specialized remote control systems.

A great variety of applications is found in the field of remote indication. Many mechanical and electrical functions in industrial processes requiring observation can be supplied with remote indicating facilities for more efficient control and better economy in operation. Remote indications of fluid levels, pressures, gate valve and other mechanical control positions are a few of the most common applications of this type of equipment. "Repeat-back" telegraph systems, common in marine usage, form a large part of this group. Such systems can be adapted to various industrial uses as aides to centralized control and to eliminate operational errors in the execution of verbal orders.

Practically all control functions suitable for remote indications can be modified for manual remote control from any desired number of stations by direct means or as auxiliaries in servo-systems. Some applications require both remote control and indication in the same system. Typical applications of manual remote control equipment include numerous types of diesel-electric power plant, traction and marine propulsion control systems and multiple engine speed control systems, in addition to common applications, such as reversing motor controls, valve controls, steering gear controls, etc. A number of such applications are shown in Figs. 8 to 11.

The receiver design used in the d-c sinusoidal system renders it suitable for a number of special automatic control applications. These include its use as an accelerating relay in d-c motor control circuits and as remote temperature indicating or auxiliary control devices.

The equipment may be operated from a single phase a-c source without change in any of its operating characteristics by the use of a suitable dry-type rectifier unit.

Since the initial cost as well as the operating expense of this d-c remote control system compares favorably with present methods, and yet affords a number of distinct advantages, it is very likely that it will serve an increasingly important role in the field of remote control.

The "Prinz" at the Crossroads

H. OMAN
Motor-Generator Section
Allis-Chalmers Mfg. Co.

FIRST-HAND account of trip aboard the Prinz Eugen, slated for atomic bomb test, destroys theory the vessel uses propulsion diesel engines.

"OPERATION CROSSROADS" is on the tongue of all scientific and atomic-minded men — as they look to Bikini Atoll where atomic bomb No. 4 will be dropped over a fleet of ancient crates and modern men-of-war to decide the future of the world's navies!

Among the not-so-old warships that may be forever wiped off the seas is the pride of German admirals, the planned forerunner of a mighty Nazi high-seas fleet that was to stop allied shipping and eventually rule the waves — the cruiser Prinz Eugen. The German engineers and shipbuilders put everything they had into making the Prinz a masterpiece of naval architecture with firepower to shoot it out with the best of contemporary cruisers, and horsepower to run away from the fastest of battleships.

We visited the Prinz Eugen less than a year after the men who guided us had been our enemies and would have shot us on the spot if we had been on the ship! But this German crew was especially courteous in explaining every detail which we asked about.

Main propulsion machinery

Quite naturally we headed for the engine room first, and it was surprising how quickly we learned German names for engine room components. Looking for the propulsion machinery, we located three screws driven by geared turbines, not four as authorities led us to believe the Prinz Eugen had during the war.

How a Nazi "Prinz" Was Born

The story of the Prinz Eugen starts way back in 1935 when an Anglo-German naval agreement was reached in which Germany was permitted to build up to 35 per cent of the naval tonnage of Great Britain and in submarines up to 45 per cent of the British tonnage. Furthermore, Germany was authorized to go up to parity with Britain in certain categories of vessels, provided that Germany would first state reasons for requiring parity in a friendly discussion with British authorities. Those were the days when it was generally accepted that Germany did not have the slightest intention of going to war with Britain.

A joker was soon apparent in this naval agreement. It turned out that Germany intended to build a fleet equivalent to 35 per cent of the entire British fleet, or about 400,000 tons. Actually the British had expected the Germans to build only up to 35 per cent of the strength of British home fleet of 351,000 tons. Furthermore, Germany announced intentions of scrapping its prewar tonnage (permitted by the Versailles Treaty), whereas Britain's navy was 30 per cent obsolete.

In April, 1939, a friendly discussion with British authorities was held by the German foreign minister and naval representatives. The British were surprised to learn that the new German cruisers (Prinz Eugen class) were armed with 8 inch guns instead of the 6 inch guns to which all other powers had agreed to limit their cruiser armament. Furthermore, Germany already had five ships in 1938, including two 26,000-ton battleships and three pocket battleships, all with speeds of over 30 knots (Prinz Eugen's top speed was 33 knots).

In welded fabrication used in German vessels after 1935 lighter metals saved considerable weight (Prinz Eugen floor plates were of aluminum) so that there was more armor and more fire power per hull in German warships than in naval vessels of other countries.

* * *

The PRINZ EUGEN is a heavy cruiser, the construction of which was undertaken in a 1936 program by Germania Shipyards. It first touched water on August 22, 1938, and was ready to raid the seas in 1940.

The vessel is 10,000 tons (compares with its contemporary, the 10,000 U.S.S. WICHITA; but 1940 Class U. S. large cruisers were 13,000 tons). The complement is 830. The size of the vessel is 654½ feet long by 71 feet wide by 15 feet draft.

Air-minded Herman Goering must have had his way about German naval vessels. The Prinz Eugen's main battery consists of eight 8 inch, 55 caliber guns while the anti-aircraft battery has twelve 4.1 inch guns and twelve 37 millimeter guns. There were also twelve 21 inch torpedo tubes and four aircraft which could be launched from one catapult. A suitable protected hangar for the aircraft was provided in the center of the ship.

In addition, diesel engines had been reported as the drive at cruising speeds. A thorough search of the vessel and questioning of our guide revealed that there were no propulsion diesel engines on the vessel, nor any provision for them.

Steam was generated in 12 high pressure water tube boilers. Maximum steam pressure was 1,020 pounds, and maximum steam temperature 470 C (880 F). The turbines were of three-stage construction for forward propulsion and two stages for astern propulsion.

Our guide had a time making us understand that between reduction gear and propeller shaft was an air (441 psi) operated dog clutch, which would automatically disengage the turbine from the propeller if the turbine developed trouble. The clutch can be engaged at any speed up to 15 knots, and can be disengaged at any speed — a very interesting development. Torque is transmitted through nests of springs. A mechanical syncroscope was provided.

The vessel was reported to have 80,000 shp and a maximum speed of 32 knots. We were told that the vessel had a maximum rating of 145,000 Continental horsepower, the equivalent of 143,000 American horsepower. The maximum speed was 33 knots, with 290 rpm on the screws. Twenty-two knots was the maximum speed with one screw (259 rpm).

Among interesting features of the vessel were the observer's range-finding periscopes. About seven of these periscopes were located in each armored bridge position. There were about eight of these armored bridges where the skipper could comfortably watch the battle inside of his two-inch armor box. They apparently had to have about six officers looking in different directions so that the skipper could be kept informed on all that was going on.

The periscope eyepieces were mounted on an expensive-looking control box about two feet on an edge. On the box were all kinds of knobs, meters, handles and cranks all carefully identified in German.

The vertical side armor was five inches in thickness and armor around the bridge and range finder positions was two inches thick.

Hunting for generators

We explored numerous dark passages and cold engine rooms to find where and how they generated the ship's service power. In a control-packed room, in traditional German thoroughness, was a complete illuminated diagram of the ship's auxiliary power system, with ampere ratings and voltages! Here is what that ship had:

NO. 1 AUXILIARY GENERATOR ROOM

1 — 460 kw, turbine driven, 230 volt d-c generator

1 — 350 kw, diesel engine driven, 230 volt d-c generator

1 — 530 kw, turbine driving a 230 kw, 1,500 rpm, 230 volt d-c generator and a 400 kva, 50 cycle, 225 volt a-c generator

NO. 2 AUXILIARY GENERATOR ROOM

2 — 460 kw, turbine driven, 230 volt d-c generators

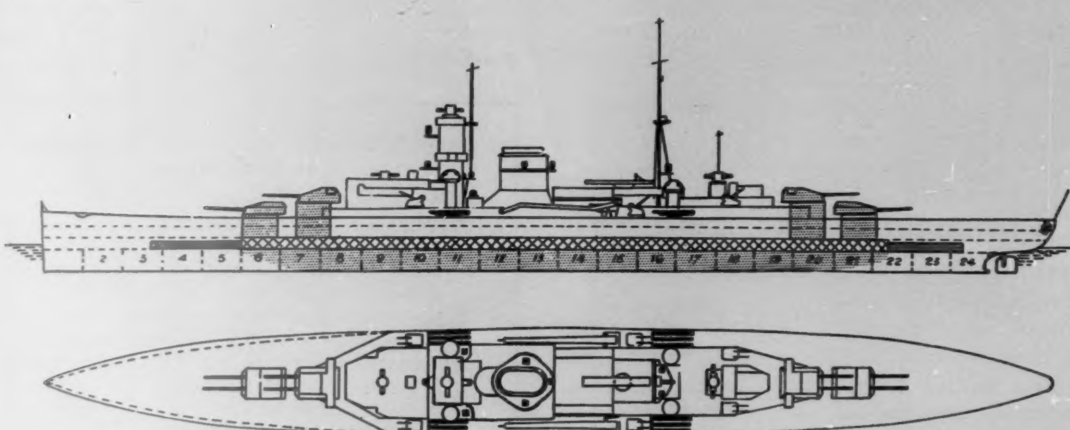
NO. 3 AUXILIARY GENERATOR ROOM

1 — Turbine driven, 460 kw, 230 volt d-c generator

3 — Diesel driven, 230 volt, d-c generators

U. S. Navy photo

PLANNED AS FORERUNNER of a mighty German high-seas fleet, the 10,000 ton heavy cruiser Prinz Eugen was intended to have sufficient horsepower to outrun any battleship and enough firepower to outshoot any cruiser. The Prinz carries four aircraft to be launched from two catapults.



Courtesy "Jayne's Fighting Ships" — Macmillan

SIDE AND TOP elevations of the Prinz Eugen, destined to be used in the test of the No. 4 atomic bomb at Operations Crossroads, are shown above.

Auxiliary generator construction

One of the generators was examined in detail. The machine was rated 460 kw, 230 volts, 1,700 rpm, 2,000 amperes continuous and 575 kw, 2,500 amperes for 30 minutes. The 10,000 rpm turbine was coupled to the generator through a reduction gear.

The generator ventilating air entered through a filter in the base of the set, and then was conducted through duct work to the rear end of the generator. Between the commutator and armature windings was a fan which exhausted air through duct work and through a cooler mounted on a nearby bulkhead. Another smaller integral fan was located at the front end of the commutator. Air from the cooler was exhausted into the engine room.

This method of cooling is unique compared with American vessels where cooling air is conducted through a closed circuit. It would seem that the German system would permit engine room fumes and vapors to collect in the generator.

The commutator was provided with three shrink rings, one at each end and one in the center. Each brushholder had two boxes so arranged that the commutator bar would come under one box and then under the second one as the commutator rotates. No effort was made to prevent brushes from jumping out of brushholders during shock.

The machines appeared to be of substantial construction and were made up of castings rather than fabricated steel, probably having been built before shock resistance of weldments was realized. Yoke diameter was about 40 inches, and overall generator length was about 60 inches. While top speed rating in American practice is usually 1200 rpm, these German generators were operating at speeds of about 1500 rpm. All machines appeared to be of two-wire construction.

In No. 3 generator room with the 460 kw generator were also three 150 kw, 230 volt diesel driven d-c generators. The engines were six cylinder, with a 13 inch stroke and 8½ inch bore, built in 1938 by "AEG."

The generators were rated 150 kw at 660 rpm. Surprisingly enough they were water-cooled, as were all other engine and turbine driven generators on the ship. The fan was located in the rear end of the generator, and again air was exhausted through a cooler into the engine room. The cooler was mounted on a bulkhead and connected to the generator by means of duct work.

In No. 1 generator room was a 530 kw, 10,000 rpm, Brown-Boveri turbine for driving an a-c generator, and a d-c generator through reduction gears at 1500 rpm was rated 230 kw, 230 volts, and was a six-pole machine.

The a-c generator was rated 400 kva, 50 cycles, 225 volts, 1,780 amps., 55 per cent power factor, and required 116 amperes excitation at 37 volts.

Additional alternating current power for communication, radar, instruments, and certain auxiliaries was obtained from motor-generator sets located in various parts of the vessel.

Ship's personnel indicated that diesel engines were used to supply auxiliary power when the ship was in port and no steam was maintained in the boilers. At the time the ship was inspected it was receiving power and heating steam from ashore.

Operators' jobs made easy

The vessel appeared to be of very neat construction, well maintained, and all machinery appeared to be in good operating condition.

All the thousands of fine instruments and controls were in perfect operating condition, the parts of the ship in use were clean and orderly, and all shiny parts were polished.

Throughout the vessel instrumentation and control was designed for maximum convenience of the operator, even to the extent of installing duplicate instruments to save an operator from looking over another's shoulder.

The main turbines were surrounded by a maze of piping and it appeared that turbine maintenance might be difficult. Yard workmen were swearing because their wrenches wouldn't fit German bolts!

Throughout the vessel were boxes, racks, and boards containing simple color coded diagrams showing the operation of the equipment in the vicinity of the diagram. It appeared that, with the aid of these diagrams, one could quickly gain a thorough understanding of the workings of a given section of the vessel . . . if he understood German.

All electrical panels had diagrams on them, or diagrams readily accessible to the operator. All machines, doors, knobs, boxes, cables, controls, and instruments were carefully labeled.

There were four boilers in the forward boiler room. Behind the boiler controls was a solid mass of pipes.

We found eight different points from which the Prinz Eugen could be steered! There must have been more. Each position had complete turbine instrumentation, rudder, and speed indicators, and several engine order telegraphs. The traditional pilot wheel had been replaced by three push buttons.

One couldn't help but speculate how much more chance for success the Germans might have had if they had only four points from which the vessel could be steered, half as many armored bridges, half as many instruments, and half as many provisions for alternate ways of running the ship. The equipment left over would have gone a long way toward building a second cruiser.

Demise of the Prinz

Only with difficulty could we find battle damage. On a lower deck between the armor plate and the outer hull was a three-foot by six-foot area where someone had apparently poured concrete. Hans showed us a patched hole in the outer hull where a British aerial torpedo had punctured the ship's skin and landed on the deck, made a big dent, but failed to explode!

One cannot help wondering what changes might have come about in the lives of men if the Nazi war lords had foreseen but a glimpse of the fate that soon awaits their once proud Prinz Eugen.

Timing Elements for Service Operations of Prinz Eugen

I. Normal Minimum Timing	
1. Full speed ahead to double stop	2 min. 30 sec.
2. Stop to full speed astern	4 min. 30 sec.
3. Full speed astern to double stop	1 min. 30 sec.
4. Stop to full speed ahead	9 min.
5. Full speed ahead to full speed astern	7 min.
6. Full speed astern to full speed ahead	10 min.
II. Flank Minimum Timing (I.E. 3" x Full Speed Astern)	
1. Full speed ahead to double stop	1 min. 15 sec.
2. Stop to full speed astern	2 min. 40 sec.
3. Full speed astern to double stop	50 sec.
4. Stop to full speed ahead	3 min. 40 sec.
5. Full speed ahead to full speed astern	5 min. 30 sec.
6. Full speed astern to full speed ahead	4 min.
III. At Manuevering Permissible Maximum R.P.M.	
Full speed ahead outboard shafts	295 r.p.m.
Full speed ahead center shaft	285 r.p.m.
Full speed astern	190 r.p.m.

Acceleration times for Prinz Eugen

FROM STANDSTILL	MINUTES
15 Sea miles per hour	2
20 Sea miles per hour	3
25 Sea miles per hour	4½
29 Sea miles per hour	7
32 Sea miles per hour	12

Save 22 to 38% Weight

WITH ALLIS-CHALMERS NEW DRY-TYPE TRANSFORMERS!

THIS REDUCED WEIGHT HELPS YOU TWO WAYS:

☞ It means wider range of installation . . . you can put these handy units almost anywhere you need secondary power — even on or next to machines!

☞ It cuts down installation cost . . . you use less mounting materials—save runs of heavy secondary copper by placing these lighter units closer to load centers.

For complete details, get in touch with your nearest Allis-Chalmers dealer or sales office, or send for new descriptive bulletin B6382.

CLASS "B" INSULATION MEANS OTHER ADVANTAGES, TOO . . .

Saves Space — reduces overall dimensions as much as 1/3 compared with class "A" insulated types.

Safer Installation — no combustible materials, no insulating liquids . . . thus, no fireproof vaults needed!

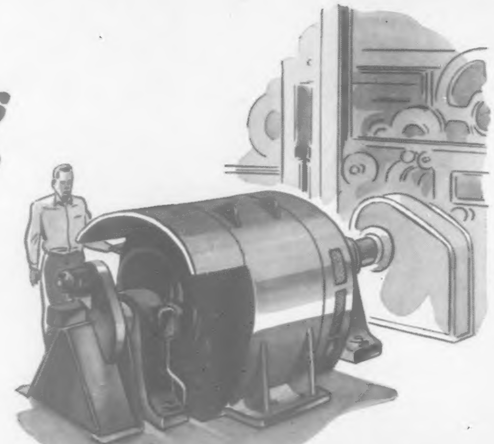
Longer-Life — resists higher temperature and protects against moisture.

Savings — 14 sizes ranging from 1½ to 300 kva, *cost no more* than class "A" insulated units. A 2015

ALLIS-CHALMERS DRY-TYPE TRANSFORMERS

C. W. BERNHARD,
MOTOR & GEN. SECT.
ELEC. DEPT.

"What! Stop a 30" Calender Roll in Less than 14" of Roll Travel!"



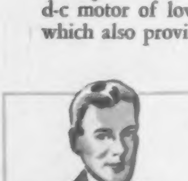
"Right! And besides that emergency stop, give us 10 to 1 speed range on the motor and hold speed *close*. The torque characteristic of our calender requires that the motor have high overload capacity at low speeds without overheating. And because of operating conditions, we want sparkless commutation too!"

B-b-u-t-t... "No buts" said Mr. Rubber Mill Man, "that's *exactly* what we need. You see, we're experimenting with new materials on our rolls, and since we can't *pre*-determine best roll speeds for them, we must have a drive that'll give us complete *range* of speeds, and at the same time, complete *protection* for our workers".

"In A Nutshell, you and the control engineers must design a calender drive system that'll give us *higher* and *lower* calender speeds, *closer* speed regulation and *sudden* emergency stopping — *all three!*" Well, we set up meetings between the control and motor designers to plan a *coordinated* design that would meet the needs.

An Automatic Speed Control incorporating both our m-g set and "Regulex" exciter was designed to hold selected speed within close limits. And, after a careful analysis of required load characteristics, we designed a 400 hp d-c motor of low inertia for quick stopping . . . and which also provided speed range from 25 to 250 rpm.

Remember That 14" Stop? After the system went in, we stopped the rolls first at 18" . . . easy. Then at 14" . . . at 12" . . . at 9"! And we probably would have stopped 'em even shorter but for possible danger of too sudden stops to the calender gear system. And commutation? After 6 months, the operators say it's perfect. A 2048



Moral: Every time Allis-Chalmers discovers new ways of solving *special* motor problems, like this one, it also learns how to build better *standard* motors for you! Watch for these new and better motors from A-C. ALLIS-CHALMERS, MILWAUKEE 1, WISCONSIN.

Wait 'til you see the NEW

ALLIS-CHALMERS MOTORS!